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Housing markets and the heterogeneous effects of monetary policy across the euro area

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ChaMP

This paper contains research conducted within the network "Challenges for Monetary Policy Transmission in a Changing World Network" (ChaMP). It consists of economists from the European Central Bank (ECB) and the national central banks (NCBs) of the European System of Central Banks (ESCB).

ChaMP is coordinated by a team chaired by Philipp Hartmann (ECB), and consisting of Diana Bonfim (Banco de Portugal), Margherita Bottero (Banca d'Italia), Emmanuel Dhyne (Nationale Bank van België/Banque Nationale de Belgique) and Maria T. Valderrama (Oesterreichische Nationalbank), who are supported by Gonzalo Paz-Pardo and Jean-David Sigaux (both ECB), 7 central bank advisers and 8 academic consultants.

ChaMP seeks to revisit our knowledge of monetary transmission channels in the euro area in the context of unprecedented shocks, multiple ongoing structural changes and the extension of the monetary policy toolkit over the last decade and a half as well as the recent steep inflation wave and its reversal. More information is provided on its website.

HOUSING MARKETS AND THE HETEROGENEOUS EFFECTS
OF MONETARY POLICY ACROSS THE EURO AREA

by Stefano Pica*

Abstract

This paper studies why monetary policy affects euro-area member states unevenly, focusing on three housing and mortgage market characteristics: homeownership rate, adjustable-rate mortgage share, and loan-to-value ratio. Using euro-area data, I show that higher values are associated with stronger consumption and mortgage rate responses. A two-country New Keynesian currency-union model with household heterogeneity reproduces observed heterogeneity and isolates three channels—cash-flow, homeownership rate, and mortgage credit—the last dominating. A Portugal case study shows amplification arises when all features are high. Closing Portugal's gap relative to the euro-area average would require reducing its LTV ratio to roughly one-third of its current level, underscoring how limited this macroprudential instrument is for addressing monetary-policy heterogeneity on its own.

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1 Introduction

The recent rapid tightening and loosening of monetary policy in the euro area has reignited an important policy question: do interest rate changes affect all member states equally? Evidence suggests they do not. Following a policy rate cut by the European Central Bank (ECB), aggregate consumption rises sharply in some countries but only modestly in others. This heterogeneity matters because it may undermine the uniform stabilization role of a common monetary policy.

A growing literature links these differences to housing wealth effects and, more broadly, to country-specific housing and mortgage market structures (see, e.g., Slacalek, Tristani, and Giovanni L Violante (2020) and Corsetti, Joao B Duarte, and Mann (2021)). This paper builds on that literature, quantifying in a structural model the role of three key institutional features: the homeownership rate (HoR), the share of adjustable-rate mortgages (ARMs), and the loan-to-value (LTV) ratio. These vary substantially across the euro area and partly drive observed cross-country differences in responses to monetary policy shocks. To illustrate the magnitude of this variation, Figure 1 shows that the ARM share is below 10% in France but exceeds 90% in Portugal, Finland, and Lithuania (EA average: 47%); the HoR is 44% in Germany but above 80% in Lithuania and Slovakia (EA average: 61%); and median LTV ratios range from 60% in Austria to 100% in the Netherlands.

This paper makes three contributions. First, I provide cross-country evidence for the euro area, showing that economies with more interest-sensitive mortgage structures—characterized by higher ARM shares, higher HoR, and higher LTV ratios—display stronger consumption and mortgage rate responses to monetary policy shocks. An overlooked fact is that these characteristics are positively correlated across countries, creating identification challenges. Second, I build a quantitative two-country New Keynesian model with rich within-country heterogeneity to quantify the role of each feature. The model shows that when all three are elevated, a larger share of high-marginal-propensity-to-consume households benefits directly from lower mortgage payments, and the resulting disposable income gains are further amplified by looser borrowing constraints. Third, I use the model to assess the impact of macroprudential tools—specifically, changes in LTV ratios—on the heterogeneity in monetary policy transmission.

Empirically, I estimate impulse responses using panel local projections, identifying monetary policy surprises via high-frequency changes in Overnight Indexed Swap rates around ECB policy announcements. The results show that countries with higher ARM shares, higher HoR, and higher LTV ratios display stronger consumption responses, and that higher ARM shares and HoR—but not LTV—are associated with stronger pass-through from nominal to

Figure 1: Housing and mortgage market characteristics across euro area countries
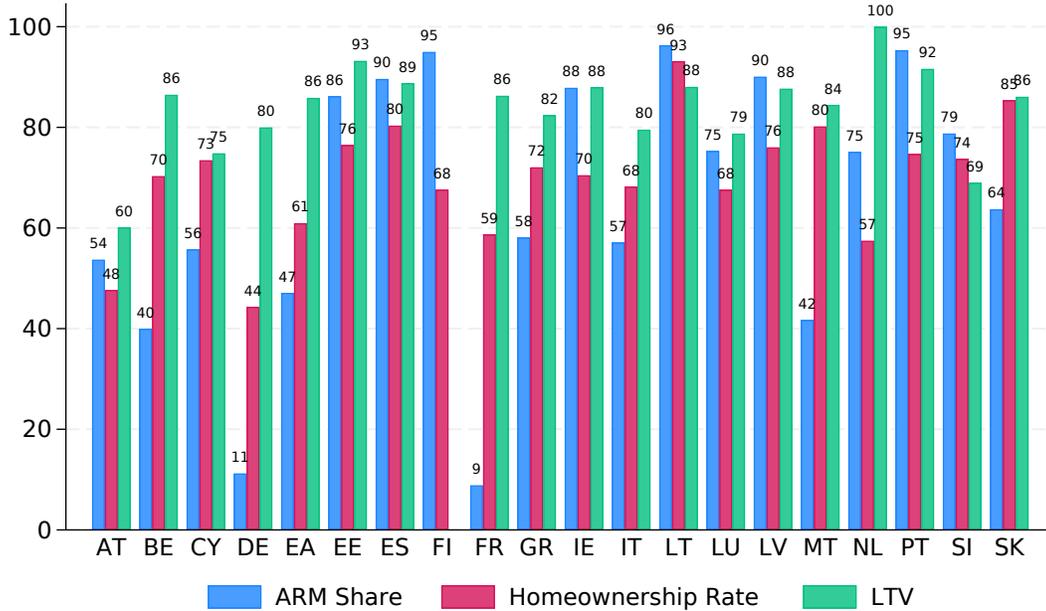
Note: Country-level housing and mortgage market characteristics in 2014, aggregated from household-level data in the Household Finance and Consumption Survey (HFCS). For each euro area country, it reports the share of adjustable-rate mortgages, the homeownership rate, and the median loan-to-value ratio.

mortgage rates. However, because these institutional features are highly correlated across countries, it is difficult to determine from the data alone whether each characteristic matters independently.

To address this, I develop a quantitative currency-union New Keynesian model with a Home-Foreign structure à la Faia and Monacelli (2008). The Foreign economy represents the aggregate euro area, while the Home economy represents an individual member state. Within each economy, households are either constrained borrowers or patient savers, and landlords rent housing to borrowers. Borrowers decide how much housing to hold, how much to borrow, and whether to be renters or mortgaged homeowners, as in Greenwald and Guren (2021), while the mortgage type mix between FRMs and ARMs is exogenously fixed to reflect institutional differences across countries. Borrowing is constrained by an LTV ratio at origination. The ECB sets policy according to a Taylor rule at the euro area level.

I calibrate the Foreign economy to match aggregate euro area moments from the housing, mortgage, and labor markets. I validate this calibration by comparing the model's impulse response functions to their empirical counterparts for the euro area following a monetary policy shock: the model reproduces both the pass-through from policy rates to average mortgage interest rates and the magnitude of the aggregate consumption response reasonably

well. The Home economy is then calibrated to each euro area member state by matching country-specific values of the ARM share, HoR, and LTV ratio, while holding all other parameters fixed at the euro area values. This framework is used to simulate a common monetary policy shock—a temporary cut in the policy rate that lowers the nominal interest rate by 25 basis points on impact.

The model reproduces the cross-country pattern of empirical heterogeneity: aggregate consumption responses range from 0.6% to 1.8%, and mortgage rate troughs range from -0.03 to -0.25 percentage points. Using Portugal—where the ARM share, HoR, and LTV are all above the euro area median—as a case study, I show that no single characteristic alone can account for the gap in responses relative to the euro area, but together they generate substantial amplification of aggregate consumption. A higher ARM share in Portugal strengthens the pass-through to average mortgage interest rates, creating a cash-flow effect that enables high-marginal-propensity-to-consume borrowers to further increase leverage through newly issued mortgages. A higher HoR expands the share of mortgaged homeowners directly benefiting from lower mortgage rates, while a higher LTV allows borrowers to take on more debt for a given increase in housing wealth.[1]

The framework also isolates three distinct channels linking housing and mortgage markets to monetary policy transmission: (i) the *cash-flow channel*, whereby changes in mortgage rates alter disposable income; (ii) the *homeownership rate channel*, whereby renters endogenously transition to homeownership and increase borrowing following a monetary expansion; and (iii) the *mortgage credit channel*, whereby easier credit conditions increase mortgage issuance. The mortgage credit channel emerges as the most important driver of cross-country differences.

Finally, I use the model to assess how macroprudential policy might affect the transmission of monetary policy. Lowering Portugal's LTV ratio would reduce part of the gap in consumption responses relative to the euro-area average, but closing it entirely would require cutting the LTV to roughly one-third of its current level. Such an extreme adjustment underscores the limited scope for realistically using this macroprudential tool on its own to mitigate monetary-policy heterogeneity within a monetary union.

Relation to the Literature. Empirically, this paper relates to studies of monetary policy effects across euro area countries, including Slacalek, Tristani, and Giovanni L Violante (2020), Almgren et al. (2022), Corsetti, Joao B Duarte, and Mann (2021), and Battistini et al. (2025). I contribute new evidence on heterogeneous mortgage rate responses—a key driver of the cash-flow channel—tightly linked to housing and mortgage market characteristics, and

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[1]In a previous version of this paper (Pica (2021)), I show that the interaction of a high HoR—proxying a high marginal propensity to consume—and a high ARM share is sufficient to generate amplification in aggregate consumption.

show that these features are positively correlated across countries, motivating a structural approach.[2]

On the theory side, I build on small open economy and currency-union models such as Gali and Monacelli (2005), Faia and Monacelli (2008), Gali and Monacelli (2008), De Paoli (2009), Corsetti, Dedola, and Leduc (2010), and Gali and Monacelli (2016), which typically feature a representative agent and closed-form solutions for optimal policy. I instead develop a quantitative multi-country model with rich household balance sheets—including long-term mortgages and rental contracts—to study the transmission of a common interest rate across countries with heterogeneous housing institutions.[3]

This work also relates to New Keynesian models with housing and mortgage debt (e.g., Iacoviello (2005); Iacoviello and Neri (2010); Rubio (2011); Calza, Monacelli, and Stracca (2013); Greenwald (2018); Garriga, Kydland, and Šustek (2021); Greenwald and Guren (2021); Dias and João B. Duarte (2022)). While these typically analyze closed economies, often the US, I study a currency union where the policy rate is set centrally and housing institutions differ across members. My approach is closest to Greenwald (2018) and Greenwald and Guren (2021), which feature long-term FRMs, but I extend them by introducing both ARMs and FRMs to match euro area data and by modeling multiple countries.

Finally, a separate literature develops heterogeneous-agent models with rich idiosyncratic risk and long-term mortgages (e.g., Chatterjee and Eyigungor (2015); Beraja et al. (2018); Berger et al. (2021); Eichenbaum, Rebelo, and Wong (2018); Wong (2019); Kaplan, Mitman, and Giovanni L. Violante (2020); Hintermaier and Koeniger (2024); Kinnerud (2025)). These typically abstract from monetary policy, endogenous prices, or institutional differences in housing and mortgage markets. I complement them by modeling multiple countries in a currency union with varying ARM shares, HoR, and LTV ratios, enabling a decomposition into mortgage credit, homeownership rate, and cash-flow channels.

2 The empirical relevance of housing and mortgage markets in the monetary transmission

This section documents how euro area countries differ in their consumption and mortgage rate responses to monetary policy shocks, and how these differences are systematically related

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[2]Turning to the US, Beraja et al. (2018) show that regional differences in housing equity shape refinancing and spending responses to rate cuts—an aspect less relevant for the euro area, where refinancing is limited. Albuquerque, Iseringhausen, and Opitz (2024) relate cross-state monetary policy effects to housing supply elasticities.

[3]See also Bellifemine, Couturier, and Jamilov (2025) and Costain, Nuño, and Thomas (2025) for multi-country heterogeneous-agent models without housing and mortgage markets.

to institutional features of housing and mortgage markets: the loan-to-value (LTV) ratio, the prevalence of adjustable-rate mortgages (ARMs), and the homeownership rate (HoR). While cross-country heterogeneity in some responses is well established in the literature (e.g. Calza, Monacelli, and Stracca 2013; Corsetti, Joao B Duarte, and Mann 2021; Almgren et al. 2022), the novel contribution here is to show that these institutional characteristics are *positively correlated* across countries. This empirical regularity, documented in Section 2.4, raises an identification challenge that the model in Section 3 is designed to address.

2.1 Identification

My empirical analysis relies on high-frequency identification of monetary policy shocks—an approach pioneered by Kuttner (2001)—and estimates dynamic responses using the local projection methodology of Jordà (2005).

Monetary policy shocks are identified using the high-frequency approach pioneered by Kuttner (2001), exploiting changes in Overnight Indexed Swap (OIS) rates in narrow windows around ECB policy announcements. Specifically, I use the "Euro Area Monetary Policy Event Study Database" of Altavilla et al. (2019), which reports changes in the median price of OIS contracts over a 10-minute window around each announcement. The baseline shock measure is the change in the 1-year OIS rate, capturing movements in longer-term borrowing costs that are particularly relevant for mortgage markets. The identifying assumption is that such changes reflect only monetary policy surprises and not other contemporaneous news.

2.2 Data and empirical specification

The sample covers 2000M1–2012M12 for 19 euro area countries, following Almgren et al. (2022).[4] Monthly shocks are constructed by summing identified 1-year OIS changes across announcements within a month. The dependent variables are aggregate consumption and average mortgage interest rates on new loans.[5]

Housing and mortgage market characteristics in the euro area are typically available only at low frequency.[6] I measure them using the second wave of the Eurosystem Household Finance and Consumption Survey (HFCS), conducted between 2013 and 2015. For each

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[4]The countries in the sample are Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Portugal, Slovakia, Slovenia, and Spain.

[5]Monthly country-level aggregate consumption is based on Almgren et al. (2022), who interpolate quarterly national accounts consumption using industrial production, retail trade, and unemployment. Mortgage rate data come from the ECB's MIR dataset; coverage from 2000 is available for Austria, Belgium, Germany, Spain, Finland, France, Ireland, Italy, the Netherlands, and Portugal.

[6]The homeownership rate, for example, is only available at annual frequencies in most countries.

country, I aggregate household-level information on mortgages to compute the share of adjustable-rate loans in the total outstanding mortgage stock. The homeownership rate is defined as the share of households owning their main residence. Finally, I calculate the median loan-to-value ratio at origination using the subset of households that purchased their primary residence with a mortgage.[7]

Dynamic responses are estimated using the panel local projection specification in equation (1), which includes country fixed effects and interacts monetary shocks with dummies for above-median ARM shares, HoR, or LTV. This approach allows for direct comparison of impulse responses between high- and low-characteristic groups while controlling for time-invariant country traits. Because most countries that have above median values for ARM share are the same as those with above median HoR or LTV, I do not include these groups simultaneously in the same specification for lack of power issues.

Specifically, for each forecast horizon $h = 0, \ldots, H$ and characteristic G, I estimate the following specification:

$$y_{t+h}^c - y_{t-1}^c = \alpha^c + \beta_h \epsilon_t^{MP} + \gamma_h \mathbb{1}_G^c \epsilon_t^{MP} + \sum_{k=1}^K \omega_{k,h} X_{t-k} + \sum_{k=1}^K \zeta_{k,h} \mathbb{1}_G^c X_{t-k} + u_t^{h,c} \qquad (1)$$

where y denotes the dependent variable of interest, α^c are country fixed effects, ϵ_t^{MP} is the monetary policy shock, $\mathbb{1}_G^c$ is a dummy variable equal to one if country c exhibits an average value of characteristic G above the cross-country median, and X is a vector of control variables.

The impulse response functions are constructed from the sequence of estimated coefficients on the shock terms, namely $\{\beta_h\}_{h=0}^H$ and $\{\gamma_h\}_{h=0}^H$. The number of lags is set to $K = 3$ months; X includes euro area aggregate output, consumer prices, the short-term rate, and the monetary policy shock. Mortgage interest rates and the short-term policy rate are expressed in annualized percentage terms, while aggregate consumption, output, and consumer prices are in logs. The monetary policy shock is standardized, with one standard deviation corresponding to 5.3 basis points.

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[7]Finland does not report mortgage information in the second wave of the HFCS. I therefore impute its ARM share and LTV ratio using data from ECB (2009), which relies on the ECB bank lending survey. Lithuania is also missing from the second HFCS wave but appears in the third; for that country, I use the third-wave data.

2.3 The role of housing and mortgage markets in the monetary transmission mechanism

Before turning to estimation results, it is useful to highlight the large cross-country variation in housing and mortgage market structures. Figure 1 illustrates the striking cross-country variation in housing and mortgage market characteristics. In France, the ARM share is under 10%, whereas in Portugal and Finland it exceeds 90% (EA average: 47%). Homeownership rates range from 44% in Germany to over 80% in Lithuania and Slovakia (EA average: 61%). Median LTV ratios are about 60% in Austria but approach 100% in the Netherlands.[8]

Figure 2 presents the estimated impulse response functions of aggregate consumption across countries grouped by the level of their housing and mortgage market characteristics. Each row of the figure corresponds to a different characteristic: ARM, HoR, and LTV. The left-hand panels show the average consumption responses (β in equation (1)) for countries below the median value of each characteristic (i.e., when $\mathbb{1}_G = 0$), while the right-hand panels report the differential responses (γ) for countries above the median (i.e., when $\mathbb{1}_G = 1$), relative to those with lower values.

Panel 2a shows that countries with a higher prevalence of ARMs exhibit consumption responses up to 0.3% larger, consistent with stronger pass-through via interest-sensitive borrowing costs. Similarly, panels 2b and 2c indicate that higher HoR and higher LTV are associated with stronger consumption responses—up to 0.4% larger. These results are consistent with the country-by-country responses reported in Figure A.2 in Appendix A, where countries such as Finland (high ARM), Spain (high HoR), and Lithuania (high LTV) display notably stronger consumption reactions to monetary policy shocks. While these individual-country plots offer a visual illustration of heterogeneity, they do not control for country fixed effects. The panel specification in equation (1) addresses this by controlling for time-invariant country characteristics—such as structural preferences for homeownership—and by providing a flexible framework to incorporate interaction terms and quantify the heterogeneous effects of housing and mortgage market institutions. It is also worth noticing that the magnitudes of the empirical impulse responses of consumption in Figure 2 and Figure A.2 are in line with the aggregate output responses reported in Almgren et al. (2022).[9]

Figure 3 presents the estimated impulse response functions of average interest rates on new mortgage loans across euro area countries, grouped by the level of their housing and mortgage market characteristics. The monetary policy shock transmits to mortgage rates,

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[8]The median LTV estimated for the Netherlands is 100%, very close to the "typical" LTV ratios from the ECB bank lending survey reported in ECB (2009) of 101%. This high value likely reflects the fact that in some countries households can take on additional debt without having to draw up a new contract.

[9]See, for example, Figure 2 and Figure A1 in Almgren et al. (2022).

Figure 2: Impulse responses of aggregate consumption to an expansionary monetary shock

(a) Dummy: high share of adjustable rate mortgages

(b) Dummy: high homeownership rate

(c) Dummy: high loan-to-value

Note: The figure shows impulse responses of aggregate consumption to an expansionary monetary surprise of one standard deviation. Responses are estimated using the panel local projection specification (1) separately for each group defined by housing and mortgage market characteristics, with robust standard errors clustered at the country level. The 95% and 68% confidence intervals are shown in light and dark blue, respectively. The estimation sample spans 2000M1–2012M12.

Figure 3: Impulse responses of mortgage interest rates to an expansionary monetary shock

(a) Dummy: high share of adjustable rate mortgages
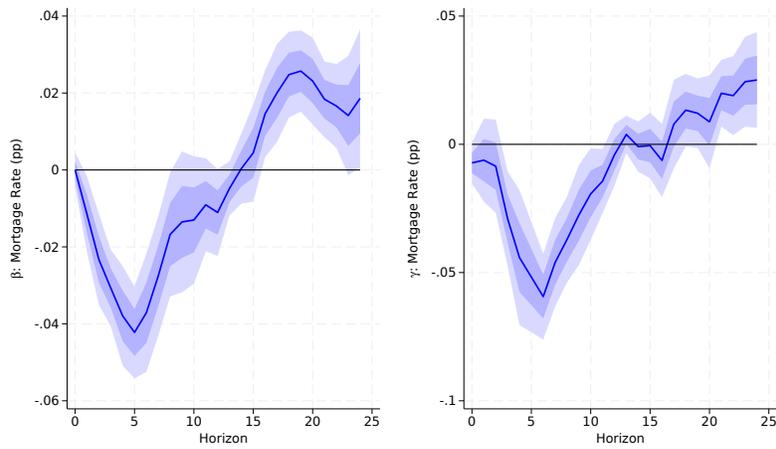
(b) Dummy: high homeownership rate
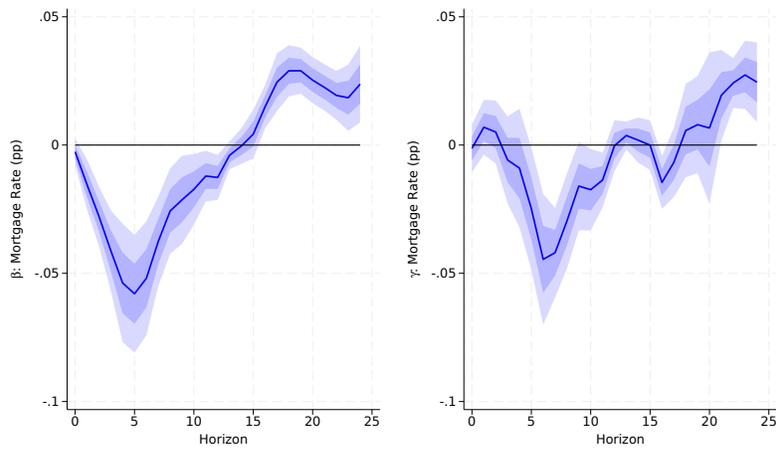
(c) Dummy: high loan-to-value
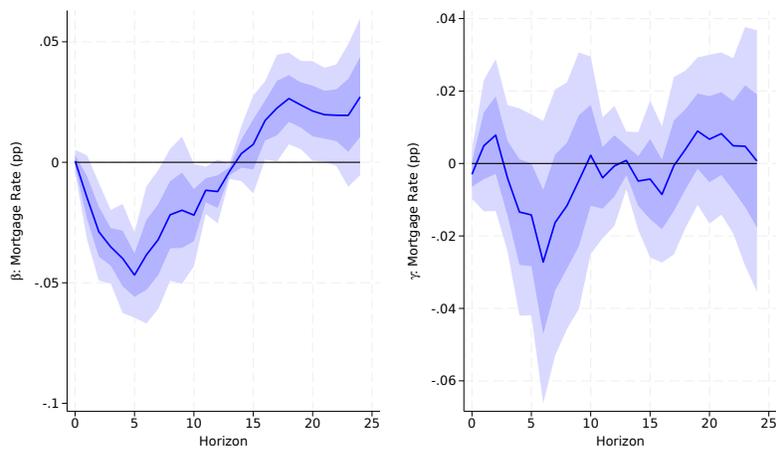
Note: The figure shows impulse responses of average interest rates on new mortgages to an expansionary monetary surprise of one standard deviation. Responses are estimated using the panel local projection specification (1) separately for each group defined by housing and mortgage market characteristics, with robust standard errors clustered at the country level. The 95% and 68% confidence intervals are shown in light and dark blue, respectively. The estimation sample spans 2000M1–2012M12.

but the extent of pass-through differs across country groups. As shown in the right-hand panels, countries with higher ARM shares and higher HoR exhibit a stronger pass-through, with mortgage rates falling by up to 5 basis points more than in countries with lower values of those characteristics. By contrast, the LTV ratio does not appear to significantly influence the cross-country heterogeneity in mortgage rate responses. These results are consistent with the country-specific estimates shown in Figure A.3 in Appendix A, where countries such as Finland (high ARM) and Spain (high HoR) display notably stronger declines in mortgage interest rates following the monetary policy shock.

Finally, it is worth emphasizing that existing research links monetary policy effectiveness to structural features of housing and mortgage markets. Calza, Monacelli, and Stracca (2013) find stronger aggregate consumption responses in countries with a higher prevalence of variable-rate mortgages, a result confirmed for the euro area by Corsetti, Joao B Duarte, and Mann (2021), who also document a strong correlation with HoR. I extend this literature in two ways. First, I provide new evidence of heterogeneous mortgage rate responses (Figure 3) and show that such differences are closely tied to housing and mortgage market characteristics. Second, I find that variation in LTV ratios significantly affects aggregate consumption responses—but not mortgage interest rates—helping reconcile mixed results in previous studies.[10]

2.4 Housing and mortgage market institutions are correlated across the euro area

The most novel empirical fact is that housing and mortgage market institutions are *positively correlated* across euro area countries. Figure 4 shows that countries with higher HoR also tend to have higher ARM shares and higher LTV ratios. Moreover, as documented by Almgren et al. (2022), countries with more "wealthy hand-to-mouth" households—most of whom are homeowners—tend to display larger output responses to monetary policy shocks.

These correlations are, to my knowledge, new to the literature. They imply that cross-country differences in monetary transmission could be driven by one institutional feature, with others appearing correlated only because they co-move structurally across countries. This multicollinearity motivates the structural analysis in Section 3, which quantifies the individual and joint contributions of ARM share, HoR, and LTV to the heterogeneous transmission of

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[10]Calza, Monacelli, and Stracca (2013) and Corsetti, Joao B Duarte, and Mann (2021) report no significant effect of LTV ratios on consumption responses. Differences likely reflect data and coverage: (i) Calza, Monacelli, and Stracca (2013) study a broad set of advanced economies, while Corsetti, Joao B Duarte, and Mann (2021) focus on 11 original euro area members, versus 19 in my sample; (ii) both use "typical" LTV ratios from the ECB bank lending survey reported in ECB (2009), whereas I use harmonized household-level data to compute median LTVs from reported purchase values and loan amounts.

Figure 4: Correlations between ARM shares, HoRs, LTV ratios, and wealthy hand-to-mouth shares
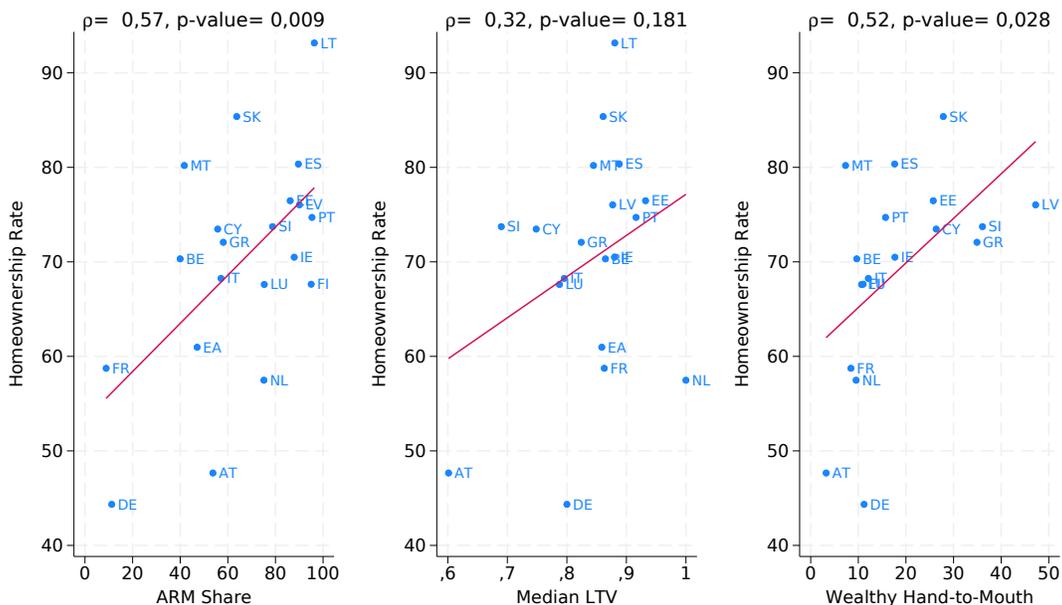
Note: These calculations are based on the Eurosystem Household Finance and Consumption Survey (HFCS). Country-level wealthy hand-to-mouth shares are computed in Almgren et al. (2022), also using HFCS data.

monetary policy.

3 A currency-union two-agent New Keynesian model

To disentangle the role of housing and mortgage market institutions in the monetary transmission mechanism, and to quantify the relative importance of the ARM share, HoR, and LTV ratio, I develop a discrete-time, two-country New Keynesian model. The framework builds on the standard currency-union setup of Faia and Monacelli (2008), enriched with detailed within-country housing and mortgage market institutions inspired by Greenwald (2018) and Greenwald and Guren (2021). The model features three housing- and mortgage-related channels: (i) the mortgage credit channel, through which shocks affect the economy via changes in mortgage issuance; (ii) the cash flow channel, through which movements in mortgage rates alter borrowers' disposable income; and (iii) the homeownership rate channel, through which endogenous transitions from renting to owning affect aggregate consumption.

This unified Home–Foreign framework enables me to assess how these institutional features shape the heterogeneous transmission of monetary policy across euro area countries. The analysis is policy-relevant: it clarifies how structural differences in national mortgage and housing markets can influence the effectiveness of a common monetary policy, both at the

aggregate euro area level and within individual member states.

3.1 Model setup

The world economy is composed of two countries: Home and Foreign. Each economy comprises three representative families—borrowers, savers, and landlords—who interact in the housing and mortgage markets. As detailed in the formal model below, the Home economy is a small open economy, while the Foreign economy is closed. Monetary policy is set at the Foreign level, and the short-term nominal interest rate is equalized across countries. I calibrate the Foreign economy to represent the euro area as a whole, and interpret and calibrate the Home economy as any individual member country within the currency union.

In terms of notation, variables with an asterisk refer to quantities in the Foreign economy, while variables without an asterisk refer to those in the Home economy. In the analysis that follows, I focus primarily on the Home economy and highlight where its structure differ from those of the Foreign economy.

Preferences. Households in this economy are indexed by $j \in \{b, s\}$, representing borrowers and savers, respectively. Borrowers belong to a family of measure χ_b and have a discount factor β_b, while the savers belong to a family of measure $\chi_s = 1 - \chi_b$ and have a higher discount factor, $\beta_s > \beta_b$. Within each family, members trade consumption and housing services, ensuring perfect insurance against idiosyncratic risk. As a result, each family can be represented by a single representative household.

Borrowers and savers maximize expected lifetime utility $\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_j^t u \left(\frac{C_{j,t}}{\chi_j}, \frac{N_{j,t}}{\chi_j}, \frac{H_{j,t}}{\chi_j} \right)$, where $C_{j,t}/\chi_j$ denotes agent j per-capita non-durable consumption, $N_{j,t}/\chi_j$ denotes per-capita labor supply, and $H_{j,t}/\chi_j$ denotes per-capita housing services. The per-period utility function is:

$$u(C, N, H) = \log(C) + \xi \log(H) - \iota \frac{N^{1+\phi}}{1 + \phi} \tag{2}$$

where ξ governs preferences over housing, ι captures the disutility of labor, and ϕ is the inverse Friesch elasticity of labor supply.

Finally, there is a family of risk-neutral landlords who maximize the present value of profits from renting out housing units to borrowers. This family aggregates to a representative firm, which is owned by the savers. As in Greenwald and Guren (2021), I assume imperfect segmentation in the housing market, a key condition for replicating realistic joint dynamics of credit conditions and house prices.

Mortgage contract. The only source of borrowing in the model economy is through mortgages, which are modeled as nominal perpetuities with geometrically declining payments,

following Chatterjee and Eyigungor (2015) and Greenwald (2018). As is standard in this class of models, impatient households (borrowers) take out mortgage loans, while patient households (savers) supply them.

A key feature of the model is the explicit differentiation between fixed-rate and adjustable-rate mortgages across countries. Specifically, I assume that borrowers hold an exogenous fraction α of FRMs and a fraction $(1-\alpha)$ of ARMs.[11] This assumption allows me to capture cross-country heterogeneity in mortgage structures by assigning different ARM shares to Home and Foreign. Although the choice of mortgage type is in principle endogenous, I model it as exogenous, consistent with the empirical observation that institutional and regulatory constraints often shape national mortgage markets.[12]

To illustrate the workings of the contract, suppose a lender issues a 1€ loan at time t. The lender receives repayments of $(1-\nu)^k(\alpha q_t^F + (1-\alpha)q_{t+k-1}^A)$€ at time $t+k$ for all $k > 0$, where ν is the share of principal repaid each period, q_t^F is the interest rate on new FRMs, and q_t^A is the interest rate on ARMs (both new and outstanding). In equilibrium, q_t^A is equal to the nominal risk-free interest rate R_t.

A fraction ρ of borrowers refinance their mortgage by repaying the outstanding balance and taking out a new loan $m_{b,t}$, subject to a loan-to-value (LTV) constraint:

$$m_{bt} \leq \theta^{LTV} p_t^h h_{bt} \tag{3}$$

where θ^{LTV} is the maximum LTV ratio, p_t^h is the house price, and h_{bt} is the size of the newly purchased house. The LTV ratio applies only at origination, consistent with prevailing mortgage market practices in both the US and the euro area.

Borrowers accumulate promised payments $X_{b,t}$ on both new and existing FRMs. The average interest rate on all outstanding FRMs is then defined as $\bar{q}_t^F \equiv X_{b,t}/M_{b,t}$, where $M_{b,t}$ is total mortgage debt.

Additional financial contracts. Savers in each economy have access to a one-period nominal bond b_t, which pays the risk-free nominal interest rate R_t and is in zero net supply. The nominal interest rate is set by the monetary authority in the Foreign economy, following a Taylor rule.

In addition, savers in both Home and Foreign can trade a complete set of state-contingent

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[11]Related contributions include Rubio (2011), who assume two types of borrowers—one for each mortgage type—and Garriga, Kydland, and Šustek (2017), who model a representative borrower that endogenously chooses the mortgage type. Both papers are calibrated to the U.S. economy.

[12]For example, Bank of Spain (2017) explain that, prior to 2015, the absence of long-term interest rate swap contracts in some countries prevented banks from hedging interest rate risk, resulting in the predominance of ARMs.

claims internationally. This assumption ensures full risk sharing across countries and yields the standard international risk-sharing condition in equilibrium.

Housing. As with mortgages, a fraction ρ of borrowers, savers, and landlords is allowed to choose the optimal housing size h_j, for $j \in \{b, s, l\}$, in each period.[13] At the beginning of each period, homeowners pay a constant maintenance cost δ on the value of their housing stock. The supply of owned housing is fixed and equal to $\bar{H}$.

Borrowers can choose between renting and owning. Following Greenwald and Guren (2021), I assume that each borrower receives a stochastic service flow from owning a home. Specifically, if borrower i owns one unit of housing, she receives $\omega_{b,t}^i$ units of the numeraire (the final good), where $\omega_{b,t}^i \sim \Gamma_{\omega,b}$ is an i.i.d. draw across borrowers and time. This idiosyncratic utility benefit induces a cutoff in each period: borrowers with sufficiently high realizations of $\omega_{b,t}^i$ choose to own, while others prefer to rent. The threshold value is endogenous and varies with macroeconomic conditions.[14]

Landlords also receive a stochastic service flow from owning housing. This heterogeneity, drawn from $\omega_{l,t}^i \sim \Gamma_{\omega,l}$, captures the idea that some housing units are more suitable for rental—due to location, quality, or moral hazard considerations. Landlords purchase housing units to convert them into rental properties for borrowers. Since the service flows received by borrowers and landlords represent utility rather than monetary gains, they are rebated to the respective agents as lump-sum transfers in equilibrium.

Finally, following Greenwald (2018), I fix saver housing demand at $h_{s,t} = \bar{H}_s$, implying that savers do not engage in housing market transactions with either borrowers or landlords.

The labor market features sticky nominal wages, modeled using standard New Keynesian wage-setting frictions (see Erceg, Henderson, and Levin (2000), Schmitt-Grohé and Uribe (2005), and Auclert, Rognlie, and Straub (2018)). Households supply labor to a continuum of unions, which set nominal wages subject to quadratic adjustment costs in utility. Details are provided in Appendix B.2.

Under a symmetric equilibrium, all households supply the same number of hours: $N_{b,t}/\chi_b = N_{s,t}/\chi_s = N_t$, where N_t is aggregate labor demand. The wage Phillips curve takes the form:

$$\pi_t^W(\pi_t^W - 1) = \frac{\varphi}{\psi} N_t \left(u^N(N_t) - \frac{\varphi - 1}{\varphi}(1 - \tau)\frac{W_t}{P_t}\tilde{u^c} \right) + \tilde{\beta}\pi_{t+1}^W(\pi_{t+1}^W - 1) \tag{4}$$

---

[13]The exogenous parameter ρ can be interpreted as a moving shock, capturing the fraction of households actively participating in the housing and mortgage markets.

[14]This heterogeneity reflects differences in preferences for ownership as well as demographic characteristics not explicitly modeled. Cross-country differences in the homeownership rate can be captured by assuming that the distribution $\Gamma_{\omega,b}$ has a different mean across countries. This difference proxies for institutional features such as rental market quality or homeownership subsidies.

where $\tilde{u}^c = \chi_b u^c(C_{b,t}/\chi_b) + \chi_s u^c(C_{s,t}/\chi_s)$ denotes the average marginal utility of consumption, and $\tilde{\beta} = \chi_b * \beta_b + \chi_s * \beta_s$ is the average discount factor across the two household types.

The borrowers choose consumption $C_{b,t}$, new mortgage borrowing $m_{b,t}$, new housing size $h_{b,t}$, and housing services $s_{b,t}$. Due to nominal wage rigidities in the labor market, they take labor income and hours worked $N_{b,t}$ as given. The endogenous state variables are: total housing holdings at the beginning of the period $H_{b,t-1}$, total outstanding mortgage balances $M_{b,t-1}$, and the total promised payments on existing fixed-rate contracts $X_{b,t-1}$. Given these, borrowers maximize expected lifetime utility:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_b^t u \left(\frac{C_{b,t}}{\chi_b}, \frac{N_{b,t}}{\chi_b}, \frac{s_{b,t}}{\chi_b} \right)$$

while facing a set of constraints. First, the budget constraint reads:

$$
\begin{aligned}
C_{b,t} \leq\ & \underbrace{(1-\tau)\frac{W_t}{P_t}N_{b,t}}_{\text{Labor income}} + \underbrace{\rho(m_{b,t} - (1-\nu)\pi_t^{-1}M_{b,t-1})}_{\text{Net mortgage issuance}} - \underbrace{\rho p_{h,t}(h_{b,t} - H_{b,t-1})}_{\text{Net housing purchases}} \\
& - \underbrace{\pi_t^{-1}\nu M_{b,t-1}}_{\text{Principal payment}} - \underbrace{\pi_t^{-1}(1-\tau)[\alpha X_{b,t-1} + (1-\alpha)q_{t-1}^A M_{b,t-1}]}_{\text{Interest payment}} - \underbrace{\delta p_{h,t}H_{b,t-1}}_{\text{Maintenance}} \\
& - \underbrace{p_{r,t}(s_{b,t} - H_{b,t-1})}_{\text{Rent}} + \underbrace{\left(\int_{\bar{\omega}_{b,t-1}} \omega d\Gamma_{\omega,b}\right)A_{b,t-1}}_{\text{Owner surplus}} + \underbrace{T_{b,t}}_{\text{Rebate}}
\end{aligned}
$$

where W_t/P_t is the real wage, π_t is the inflation rate, $p_{h,t}$ is the house price, $p_{r,t}$ is the rental rate, ω denotes the utility benefit from homeownership, and $A_{b,t-1}$ is a term that does not influence the main results and is detailed in Appendix B.1.1. The term $T_{b,t}$ denotes a lump-sum transfer that rebates, in real terms, the taxed income, the deducted interest payments, and the utility benefits from homeownership.

Second, the borrower is subject to the LTV constraint defined by equation (3). Finally, the laws of motion for the state variables are:

$$
\begin{aligned}
M_{b,t} &= \underbrace{\rho m_{b,t}}_{\text{New loans}} + \underbrace{(1-\rho)(1-\nu)\pi_t^{-1}M_{b,t-1}}_{\text{Old loans}} \\
X_{b,t} &= \underbrace{\rho q_t^F m_{b,t}}_{\text{New loans}} + \underbrace{(1-\rho)(1-\nu)\pi_t^{-1}X_{b,t-1}}_{\text{Old loans}} \\
H_{b,t} &= \underbrace{\rho h_{b,t}}_{\text{New housing}} + \underbrace{(1-\rho)H_{b,t-1}}_{\text{Old housing}}
\end{aligned}
$$

The landlords belong to a family whose objective is to purchase housing $h_{l,t}$ and rent it

to borrowers. The only endogenous state variable is the total stock of housing held at the beginning of the period, $H_{l,t-1}$. Since landlords are risk-neutral, they can be aggregated into a representative firm owned by the savers. This firm maximizes the expected present value of profits: $\mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^s F_t$, where $\Lambda_{0,t}^s$ is the stochastic discount factor of the savers, and F_t denotes the flow of profits in period t. The landlord's budget constraint is given by:

$$F_t \leq \underbrace{p_{r,t}H_{l,t-1}}_{\text{Rent}} - \underbrace{\rho p_{h,t}(h_{l,t} - H_{l,t-1})}_{\text{Net housing purchases}} - \underbrace{\delta p_{h,t}H_{l,t-1}}_{\text{Maintenance}} + \underbrace{\left(\int_{\bar{\omega}_{l,t-1}} \omega d\Gamma_{\omega,l}\right)A_{l,t-1}}_{\text{Owner surplus}} + \underbrace{T_{l,t}}_{\text{Rebate}}$$

where the quantity $T_{l,t}$ rebates lump-sum the utility benefits from ownership received by the landlords. Finally, the law of motion of housing stock $H_{l,t}$ is:

$$H_{l,t} = \underbrace{\rho h_{l,t}}_{\text{New housing}} + \underbrace{(1-\rho)H_{l,t-1}}_{\text{Old housing}}$$

The savers choose consumption $C_{s,t}$, bond holdings B_t, new mortgage issuance $m_{s,t}$, and the size of new housing purchases $h_{s,t}$.[15] As in the case of borrowers, they take labor supply $N_{s,t}$ as given due to wage-setting frictions in the labor market. The endogenous state variables are: the stock of housing held at the beginning of the period $H_{s,t-1}$, the outstanding balance of mortgage debt $M_{s,t-1}$, the stream of promised payments on existing contracts $X_{s,t-1}$, and the bond position carried over from the previous period B_{t-1}. Savers maximize:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_s^t u\left(\frac{C_{s,t}}{\chi_s}, \frac{N_{s,t}}{\chi_s}, \frac{H_{s,t}}{\chi_s}\right)$$

while facing a set of constraints. First, the budget constraint reads:

$$
\begin{aligned}
C_{s,t} \leq{}& \underbrace{(1-\tau)\frac{W_t}{P_t}N_{s,t}}_{\text{Labor income}} - \underbrace{\rho(m_{s,t} + (1-\nu)\pi_t^{-1}M_{s,t-1})}_{\text{Net mortgage issuance}} - \underbrace{\rho p_{h,t}(h_{s,t} - H_{s,t-1})}_{\text{Net housing purchases}} + \underbrace{\pi_t^{-1}\nu M_{s,t-1}}_{\text{Principal payment}} + \underbrace{T_{s,t}}_{\text{Rebate}} \\
&+ \underbrace{\pi_t^{-1}[\alpha X_{s,t-1} + (1-\alpha)q_{t-1}^A M_{s,t-1}]}_{\text{Interest payment}} - \underbrace{(R_t^{-1}B_t - \pi_t^{-1}B_{t-1})}_{\text{Net bond purchases}} - \underbrace{\delta p_{h,t}H_{s,t-1}}_{\text{Maintenance}} + \underbrace{F_t}_{\text{Profits landlord}} \quad (5)
\end{aligned}
$$

where the quantity $T_{s,t}$ represents a lump-sum rebate of taxed income.

Second, the laws of motion for the mortgage balance $M_{s,t}$, the total stream of promised

---

[15]The exposition here assumes that savers also choose $h_{s,t}$, although in the model solution I assume it constant as in Greenwald (2018) (see the Calibration section for more details).

payments on existing debt $X_{s,t}$, and the housing stock $H_{s,t}$ are given by:

$$M_{s,t} = \underbrace{\rho m_{s,t}}_{\text{New loans}} + \underbrace{(1-\rho)(1-\nu)\pi_t^{-1}M_{s,t-1}}_{\text{Old loans}}$$

$$X_{s,t} = \underbrace{\rho q_t^F m_{s,t}}_{\text{New loans}} + \underbrace{(1-\rho)(1-\nu)\pi_t^{-1}X_{s,t-1}}_{\text{Old loans}}$$

$$H_{s,t} = \underbrace{\rho h_{s,t}}_{\text{New housing}} + \underbrace{(1-\rho)H_{s,t-1}}_{\text{Old housing}}$$

Finally, I assume that savers—both in Home and Foreign—have access to complete markets at both the national and international level.[16] This assumption implies the standard international risk-sharing condition derived in Chari, Kehoe, and McGrattan (2002): $u_{s,t}^{*,c} = u_{s,t}^c Q_t$, where $u_{s,t}^{*,c}$ and $u_{s,t}^c$ denote the marginal utility of consumption for savers in the Foreign and Home economies, respectively, and Q_t is the real exchange rate. Intuitively, the marginal utility of one unit of consumption in the Foreign economy must equal that of one unit of consumption in the Home economy, adjusted by the real exchange rate.

The final good sector is operated by perfectly competitive firms that employ a simple linear production technology under flexible prices: $Y_t = N_t$. Given perfect competition and constant returns to scale, the price of the final good equals the nominal wage, i.e., $P_t = W_t$, and firms make zero profits. This implies two key results: (a) the real wage is constant and equal to one, $W_t/P_t = 1$; and (b) price inflation equals wage inflation, that is, $\pi_t \equiv P_t/P_{t-1} = \pi_t^W \equiv W_t/W_{t-1}$.

The world economy consists of two countries—Home and Foreign—where, following Faia and Monacelli (2008), the Home economy is assumed to be small relative to Foreign.

In each country, aggregate consumption is a composite of domestic and imported goods, with each bundle comprising imperfectly substitutable varieties. The full derivations, including the construction of consumption-based price indices and the goods-market equilibrium, are provided in Appendix B.3. The latter yields the following equilibrium condition for Home output:

$$Y_t = \left(\frac{P_{H,t}}{P_t}\right)^{-\eta}[(1-\lambda)Y_t + \lambda Q_t^\eta Y_t^*] \tag{6}$$

Equation (6) shows that both Foreign output and the real exchange rate directly influence Home output. By contrast, due to its small size, the Home economy has no effect on Foreign output or on the dynamics of Q_t.

---

[16]The state-contingent assets traded are omitted from the budget constraint (5) for expositional clarity. This is standard in the literature; see, for instance, Gali and Monacelli (2005), Gali and Monacelli (2008), Faia and Monacelli (2008), and De Paoli (2009).

The monetary authority operates at the level of the currency union and thus conducts policy from the perspective of the Foreign economy, which represents the monetary union as a whole. Monetary policy follows a Taylor rule with a white noise shock ϵ_t, consistent with standard practice in the New Keynesian literature. The specification is based on the empirical rule estimated for the euro area by Christoffel, Coenen, and Warne (2008):

$$
\begin{aligned}
\log(R_t^*/R_{ss}^*) &= \phi_R \log(R_{t-1}^*/R_{ss}^*) + (1 - \phi_R)\phi_\pi \log \pi_{t-1}^* \\
&\quad + \phi_{\Delta\pi}(\pi_t^* - \pi_{t-1}^*) + \phi_{\Delta Y}(Y_t^* - Y_{t-1}^*) + \epsilon_t
\end{aligned} \tag{7}
$$

Since monetary policy is conducted at the union level, a single nominal interest rate is applied across all member countries: $R_t = R_t^*$.[17]

A competitive equilibrium is a sequence of endogenous state variables ($H_{b,t-1}$, $H_{s,t-1}$, $H_{l,t-1}$, $M_{b,t-1}$, $M_{s,t-1}$, $X_{b,t-1}$, $X_{s,t-1}$, $B_{s,t-1}$), borrower controls ($C_{b,t}$, $m_{b,t}$, $h_{b,t}$, $s_{b,t}$), saver controls ($C_{s,t}$, $m_{s,t}$, $h_{s,t}$, B_t), landlord controls ($h_{l,t}$), and prices (R_t, q_t^A, q_t^F, W_t/P_t, $p_{h,t}$, $p_{r,t}$, π_t, π_t^W, $P_{H,t}/P_t$, Q_t) such that: (i) households and firms maximize their objective values, and (ii) the following markets clear:

- Bonds are in zero net supply: $B_t = 0$;
- The labor market clears: $N_{b,t} + N_{s,t} = N_t$;
- The mortgage market clears: $M_{b,t} + M_{s,t} = 0$;
- The housing market clears: $H_{b,t} + H_{s,t} + H_{l,t} = \bar{H}$;
- Housing services: $s_{b,t} = H_{b,t-1} + H_{l,t-1}$;
- The goods market clears: $C_{b,t} + C_{s,t} + \delta p_t^h \bar{H} = Y_t$.

3.2 Equilibrium conditions and economic channels

This section highlights selected optimality conditions to illustrate the economic channels originating from the housing and mortgage markets and to explain the sources of differential monetary policy responses. The remaining equilibrium conditions are reported in Appendix B.1.

3.2.1 The cash-flow channel

Cross-country differences in household responses to monetary policy partly reflect differences in the pass-through of policy rates to average mortgage interest rates. The average rate

---

[17]This condition is an equilibrium result rather than an assumption. Technically, the central bank fixes the nominal exchange rate across countries at a constant level, $\zeta_t = \bar{\zeta}$, in the notation of Appendix B.3. Given uncovered interest parity, this implies that nominal interest rates are equalized across countries.

on newly issued mortgages is defined as $\bar{q}_t^{new} \equiv \alpha q_t^F + (1-\alpha)q_t^A$, while the average rate on outstanding mortgages is $\bar{q}_t^{out} \equiv \alpha \bar{q}_t^F + (1-\alpha)q_t^A$. The former influences the demand for new mortgage credit, whereas the latter determines interest payments on the existing mortgage stock—i.e., the *cash-flow channel.*

As discussed in Appendix B.1.4, the interest rate on ARMs is set equal to the nominal interest rate: $R_t = q_t^A + 1$. Since nominal interest rates are equalized across countries, ARM rates are also equalized: $q_t^{*,A} = q_t^A$. Similarly, Appendix B.1.5 shows that, under the calibration in Section 3.3, movements in FRM rates are identical across Home and Foreign: $q_t^{*,F} = q_t^F$. Consequently, cross-country differences in $\bar{q}_t^{new}$ and $\bar{q}_t^{out}$ arise solely from differences in mortgage type shares, α (FRM) and $1-\alpha$ (ARM).

These results follow from the first-order condition for newly issued mortgages by savers:

$$\Omega_{s,t}^m + q_t^F \Omega_{s,t}^x = 1 \tag{8}$$

which states that the total marginal benefit from issuing one euro of mortgage credit (left-hand side) equals its marginal cost (right-hand side). The benefit combines the continuation value of mortgage issuance, $\Omega_{s,t}^m$, and the continuation value of promised initial payments, $\Omega_{s,t}^x$, weighted by the FRM interest rate q_t^F. The continuation values are defined in Appendix B.1.

Following a cut in nominal interest rates, countries with a higher ARM share experience stronger pass-through to average mortgage rates. This is because the ARM rate moves one-for-one with the policy rate, and its greater weight in the mortgage portfolio amplifies the impact on borrowers' disposable income. This mechanism is the source of heterogeneity in the cash-flow channel.

Finally, notice that, because borrowers have a higher marginal propensity to consume, a larger measure of borrowers amplifies the aggregate consumption response to monetary policy. When credit conditions ease, a greater fraction of households becomes exposed to the cash-flow channel, benefiting from lower mortgage payments and increasing consumption more strongly.

3.2.2   The homeownership rate channel

In the model, borrowers consist of mortgaged homeowners and renters, while savers are outright homeowners. Following Greenwald and Guren (2021), all borrowers with utility benefit $\omega_{i,t} > \bar{\omega}_{b,t}$ choose to become homeowners, where the threshold $\bar{\omega}_{b,t}$ is implicitly defined by the housing market clearing condition:

$$1 - \Gamma_{\omega,b}(\bar{\omega}_{b,t}) = \frac{H_{b,t}}{H_{b,t} + H_{l,t}}, \tag{9}$$

where the left-hand side is the fraction of borrowers choosing to own, and the right-hand side is the share of borrower-inhabited housing owned by borrowers.

Similarly, market clearing in the rental housing market imposes for landlords:

$$1 - \Gamma_{\omega,l}(\bar{\omega}_{l,t}) = \frac{H_{l,t}}{H_{b,t} + H_{l,t}}. \tag{10}$$

Equations (9)–(10) imply that, for a given measure of borrowers, countries with higher homeownership rates allocate a larger share of housing to borrowers relative to landlords, enabling borrowers to take on more debt. During an expansion, renters can transition into homeownership, further increasing the share of households able to access cheaper mortgage credit. This mechanism constitutes the *homeownership rate channel.*

3.2.3 The mortgage credit channel

The *mortgage credit channel*—defined by Greenwald (2018) as the transmission of primitive shocks via changes in mortgage issuance—is captured in the model by the LTV constraint in equation (3). Economies in which households can borrow more—either because the average interest rate on new mortgages is lower or because the maximum LTV ratio θ^{LTV} is higher—enable borrowers to release additional resources for consumption, thereby amplifying the shock's effects on aggregate demand and the wider economy.

3.3 Calibration and validation

The model is calibrated at a quarterly frequency and features a two-country structure: a small open economy (Home) and a closed economy (Foreign), with the latter independent of any Home-specific features. The Foreign economy is calibrated to represent the euro area (EA), while the Home economy is calibrated separately for each euro area country. Although the Home economy does not affect the Foreign block, Foreign developments influence Home through equation (6), requiring that each Home calibration be conducted jointly with that of the Foreign economy.

The Foreign calibration is validated by comparing the model's impulse responses to their empirical euro area counterparts following a monetary policy shock. The Home economy inherits all Foreign parameters except those governing housing and mortgage market institutions, which are calibrated to match country-specific moments from the HFCS (see Section 2.2 for a discussion of the data). Cross-country heterogeneity in the model therefore stems solely from differences in housing and mortgage market characteristics.

Table 1: Calibration for the euro area (Foreign economy)

Parameter	Name	Value	Internal	Target/Source
			Demographics and Preferences	
Borrower discount factor	β_b^*	0.96	N	Greenwald (2018)
Saver discount factor	β_s^*	0.993	N	Average 10Y rate, 2007-2019
Borrower measure	χ_b^*	0.591	N	Fraction of renters & mortgaged homeowners from the HFCS
Labor disutility	ι^*	0.836	Y	$N_{SS}^* = 1$
Inverse Frisch elasticity	ϕ^*	0.5	N	Burriel, Fernández-Villaverde, and Rubio-Ramirez (2010)
Housing preference	ξ^*	0.399	Y	$M_{SS}^*/Y_{SS}^* = 0.428$
Landlord het. (location)	$\mu_{\omega,l}^*$	-0.002	N	Greenwald and Guren (2021)
Landlord het. (scale)	$\sigma_{\omega,l}^*$	0.020	N	Greenwald and Guren (2021)
Borrower het. (location)	$\mu_{\omega,b}^*$	-0.0158	Y	Homeownership rate from the HFCS
Borrower het. (scale)	$\sigma_{\omega,b}^*$	0.008	N	Greenwald and Guren (2021)
			Housing and Mortgages	
ARM share	$1-\alpha^*$	0.471	N	Share of adjustable rate mortgages from the HFCS
Mortgage amortization	ν^*	0.435%	N	Greenwald (2018)
Income tax rate	τ^*	0.24	N	Christoffel, Coenen, and Warne (2008)
Max LTV ratio	θ_{LTV}^*	0.859	N	Median LTV ratio from the HFCS
Housing depreciation	δ^*	0.005	N	Standard
Refinancing rate	ρ^*	0.034	N	Greenwald (2018)
Saver housing stock	$\bar{H}_s^*$	14.847	Y	$\bar{H}_s^* = \bar{h}_{s,SS}^*$
Total housing stock	$\bar{H}^*$	21.394	Y	$p_{SS}^{*,h} = 1$
			Labor Market	
Elasticity subst. tasks	φ^*	21	N	Auclert, Rognlie, and Straub (2018)
Disutility wage changes	ψ^*	251.3	Y	Implies standard value for wage flexibility: 0.1
			Taylor Rule	
Interest rate smoothing	ϕ_R	0.865	N	Christoffel, Coenen, and Warne (2008)
Response to inflation	ϕ_π	1.904	N	Christoffel, Coenen, and Warne (2008)
Response to change in inflation	$\phi_{\Delta\pi}$	0.185	N	Christoffel, Coenen, and Warne (2008)
Response to change in output	$\phi_{\Delta Y}$	0.147	N	Christoffel, Coenen, and Warne (2008)

Note: The model is calibrated at steady state and at a quarterly frequency. The "Internal" column indicates whether the parameter is calibrated to match a targeted moment internally (Y) or derived analytically in closed form (N).

3.3.1 Calibration of the Foreign economy (euro area) and validation

The parameters used to calibrate the Foreign economy, which represents the euro area, are summarized in Table 1. Parameters standard in the New Keynesian literature are set externally, while others—particularly those related to the housing and mortgage markets—are calibrated internally to normalize steady-state quantities or to match empirical moments. As a general rule, I assign U.S. values to parameters that have not been estimated for the euro area and for which no relevant microdata are available.

Demographics and preferences. To calibrate the borrower population share χ_b^*, I draw on the second wave of the HFCS, discussed in Section 2.2. In the model, borrowers include both renters and mortgaged homeowners, while savers correspond to outright homeowners. The HFCS indicates that borrowers represent approximately 59% of the euro area population (39% renters and 20% mortgaged homeowners).

To capture long-run interest rate behavior, I calibrate the saver discount factor β_s^* to match the average 10-year euro area bond yield over the period 2007–2019. The borrower

discount factor β_b^* is set externally to the value used by Greenwald (2018) (0.96). Varying this parameter within a plausible range (e.g., to 0.97 as in Iacoviello and Neri (2010)) has negligible impact on the model's results.

The labor disutility parameter ι^* is calibrated so that steady-state aggregate labor equals one. I set the Frisch elasticity of labor supply to 2, a standard value in the literature and one that Burriel, Fernández-Villaverde, and Rubio-Ramirez (2010) estimate for Spain; I assume this estimate to be representative of the euro area as a whole. The housing preference parameter ξ^* is calibrated to match the 2014 ratio of total mortgage stock to GDP in the euro area, reported as 0.428 in Hypostat (2019).

Finally, heterogeneity in borrower and landlord utility from homeownership is calibrated following Greenwald and Guren (2021). Specifically, the distributions of ownership utility are modeled as logistic:

$$\Gamma_{\omega,j}(\omega) = \left[1 + \exp\left\{-\left(\frac{\omega - \mu_{\omega,j}}{\sigma_{\omega,j}}\right)\right\}\right]^{-1} \qquad j \in \{b, l\} \tag{11}$$

These distributions determine the slopes and intercepts of housing demand and supply curves in the price-to-rent and homeownership space. The scale parameters and the landlord location parameter are set to the U.S. values in Greenwald and Guren (2021), while the borrower location parameter $\mu_{\omega,b}^*$ is internally calibrated to match the 20% share of mortgaged homeowners in the HFCS. Since savers represent outright homeowners in the model, this implies a total homeownership rate of 61%, in line with the data.

Housing and mortgages. Parameters related to housing and mortgage markets are primarily calibrated using HFCS microdata. The ARM share in the euro area, $1 - \alpha^*$, is set to 47.1%. The LTV parameter θ_{LTV}^* is set to the median value observed in the HFCS, 0.859.

The saver fixed level of housing demand $\bar{H}_s^*$ is fixed at the optimal value the saver would choose in steady-state, $\bar{H}_{s,SS}^*$. The aggregate housing stock $\bar{H}^*$ is calibrated to normalize the steady-state real house price to one. Lacking euro area microdata on refinancing and amortization behavior, I follow Greenwald (2018) and adopt U.S. values for the refinancing rate ρ^* and the amortization rate ν^*.

Labor market. Following Auclert, Rognlie, and Straub (2018), I set the elasticity of substitution across labor types, φ^*, to the U.S. value commonly used in the literature (e.g., Christiano, Eichenbaum, and Evans (2005)). The household disutility from wage adjustment, ψ^*, is calibrated such that the implied wage flexibility parameter κ_w^* equals the standard value of 0.1: $\kappa_w^* = \frac{\varphi^*}{\psi^* N^* u^{*,N}(N^*)}$, where $u^{*,N}(N^*)$ denotes the marginal disutility of labor at the aggregate labor level N^*.

Figure 5: Impulse response functions of euro area variables: model vs. data
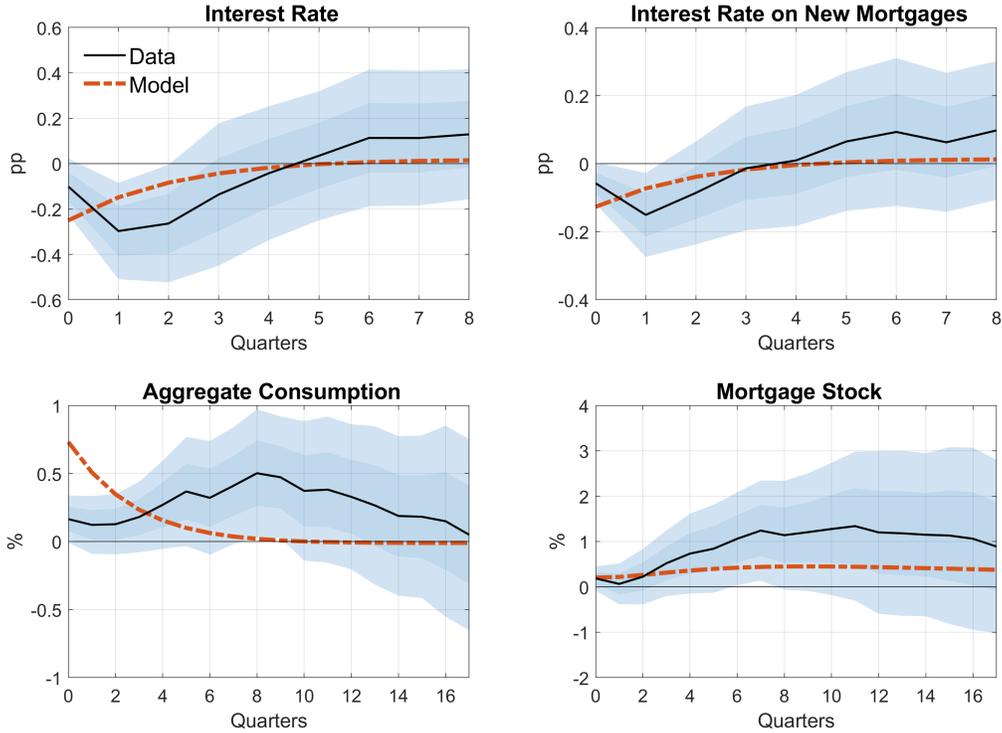
Note: The figure displays both model-based and empirical impulse response functions for selected euro area variables. Model-based responses are derived from a one-time shock ϵ_t in the Taylor rule (7), normalized to induce a 25 basis point decline in the short-term interest rate on impact. The empirical responses are estimated using equation (A.1), with 95% and 68% confidence intervals shown in light and dark blue, respectively.

The income tax rate is set to the value estimated for the euro area by Christoffel, Coenen, and Warne (2008).

Monetary policy. The monetary authority is assumed to follow the Taylor rule specified in equation (7), with coefficients calibrated to the euro area estimates from Christoffel, Coenen, and Warne (2008).

Model validation. To validate the calibration of the Foreign economy, Figure 5 compares the model-implied impulse response functions to a transitory monetary policy shock ϵ_t—introduced via the Taylor rule in equation (7)—with their empirical counterparts for the euro area. The empirical euro area impulse responses are estimated using the country-by-country local projection specification in equation (A.1), initially at monthly frequency (as shown in Figure A.1) and subsequently aggregated to quarterly frequency to allow comparison with the model output.

The empirical impulse responses display greater persistence than those generated by the model, which abstracts from standard propagation mechanisms—such as capital adjustment

costs—that typically strengthen internal amplification. This limitation, however, is not central to the paper's main contribution, which concerns the comparison between the relative magnitude of euro-area responses and those at the country level (see next section). To facilitate a more balanced comparison between empirical and model-implied dynamics, the empirical impulse responses are rescaled so that the cumulative interest-rate response over the first two quarters matches that of the model.

The model performs well in quantitatively matching both the pass-through to interest rates on new mortgage loans and the consumption response, although for the latter it predicts a peak response of about 0.7 %, compared with roughly 0.5% in the data, where the peak occurs after two years. By contrast, the response of the mortgage stock in the model is more persistent—reflecting its law of motion—and peaks around the same horizon as in the data, although the empirical response exhibits a somewhat larger amplitude.

3.3.2 Calibration of the Home economy (each euro area country)

The Home economy is calibrated separately for each euro area country, with heterogeneity arising solely from differences in housing and mortgage market parameters. All other parameters are fixed at the euro area values reported for the Foreign economy in Table 1. The four parameters highlighted in red are instead calibrated to match country-specific moments from the HFCS, as reported in Table 2.

The first country-specific parameter is the average utility benefit from owning, $\mu_{\omega,b}$, which captures institutional and structural features of national housing markets—such as rental sector quality and homeownership subsidies. It is internally calibrated to match each country's share of mortgaged homeowners (Table 2), a key driver of the marginal propensity to consume. The borrower share χ_b is similarly set to match the observed combined share of renters and mortgaged homeowners.

The remaining country-specific parameters are the ARM share $1 - \alpha$ and the LTV ratio θ, also taken from Table 2. The ARM share determines the strength of the cash-flow channel, while the LTV ratio contributes to govern the potency of the mortgage credit channel.

International finance. The final parameters to calibrate for the Home economy relate to international trade: the home bias parameter λ and the elasticity of substitution η between domestic and foreign consumption bundles, as specified in equation (6). Following Burriel, Fernández-Villaverde, and Rubio-Ramirez (2010), who estimate a DSGE model for Spain, I adopt their values for all euro area countries and set $\lambda = 0.187$ and $\eta = 7.671$ uniformly across countries.

Although home bias implies that both foreign output and the real exchange rate affect

Table 2: Housing and mortgage market parameters for each euro area country (Home economy)

Country	ARM share	HoR	Outright HoR	Mortgaged HoR	LTV
Austria	53.7	47.7	32.2	15.5	0.60
Belgium	40.0	70.3	38.4	31.9	0.86
Cyprus	55.7	73.5	39.2	34.3	0.75
Estonia	86.2	76.5	57.8	18.7	0.93
Finland	95.0	67.6	34.8	32.8	0.86
France	8.9	58.7	39.8	19.0	0.86
Germany	11.2	44.3	27.8	16.5	0.80
Greece	58.1	72.1	60.6	11.4	0.82
Ireland	87.9	70.5	36.6	33.9	0.88
Italy	57.1	68.2	58.6	9.7	0.80
Latvia	90.1	76.0	62.6	13.5	0.88
Lithuania	96.3	93.2	82.8	10.4	0.88
Luxembourg	75.3	67.6	38.5	29.1	0.79
Malta	41.7	80.2	64.3	15.9	0.84
Netherlands	75.1	57.5	16.9	40.6	1.00
Portugal	95.3	74.7	42.0	32.7	0.92
Slovakia	63.7	85.4	70.2	15.2	0.86
Slovenia	78.8	73.7	65.6	8.2	0.69
Spain	89.6	80.3	50.8	29.6	0.89
Euro area	47.1	61.0	40.9	20.0	0.86

Note: The table lists housing and mortgage market characteristics for each euro area country estimated from the second wave of HFCS.

domestic output through equation (6), this effect is quantitatively modest. Re-calibrating the model under the assumption of full autarky ($\lambda = 0$) yields nearly identical steady-state values and dynamic responses for the Home economy.

3.3.3 Model-implied marginal propensity to consume

In this class of models, the marginal propensity to consume (MPC) reflects the interaction of the model's structural features—preferences, constraints, and laws of motion—as well as the underlying parameterization. The borrower–saver framework at the core of the model naturally generates heterogeneous MPCs across households. In the calibration of the Foreign economy to the euro area, borrowers exhibit an MPC of 54%, while savers display an MPC of 22%.[18]

Each calibrated Home economy features its own MPC profile, shaped by the economy-specific housing and mortgage market parameters. A key determinant is the share of mortgaged homeowners: a higher share implies a larger fraction of the housing stock allocated to borrowers

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[18]The MPC is computed by simulating a one-time transfer shock to households' budget constraints in general equilibrium and measuring the resulting impact consumption response.

(see Equations (9)–(10) and Section 3.2.2), allowing them to take on proportionally more debt during an expansion. Loan-to-value ratios play an additional role: a higher LTV increases the MPC by enabling borrowers to expand leverage more aggressively when conditions loosen, ceteris paribus.

It is also worth emphasizing that, within the model, mortgaged homeowners behave as wealthy hand-to-mouth (Wh2M) agents: they own housing but consume out of current income and available borrowing capacity. The calibrated share of mortgaged homeowners which I estimate from the HFCS aligns closely with empirical estimates of Wh2M households reported by Almgren et al. (2022) and shown in the right panel of Figure 4. For the major euro-area economies, Wh2M households represent 11% of the population in Germany, 8% in France, 12% in Italy, and 18% in Spain—figures very similar to the corresponding shares of mortgaged homeowners reported in Table 2.

4 Model results

This section shows the effects that ARM shares, HoR, and LTV play in the transmission mechanism of monetary policy in the euro area. I linearize the model equations to first-order around the deterministic steady state and plot the relevant impulse response functions to a one-time shock ϵ_t in the Taylor rule (7).

4.1 Heterogeneous monetary transmission

Countries with different housing and mortgage market structures respond very differently to the same monetary policy shock. In the model, a 25 basis point fall in the nominal interest rate generates peak aggregate consumption responses ranging from 0.6% to 1.8%, and mortgage rate troughs from −0.03 to −0.25 percentage points (Figure 6a). These differences arise solely from cross-country heterogeneity in ARM shares, HoR, and LTV ratios. The calibration strategy follows Section 3.3: the Foreign economy is calibrated to the euro area, while the Home economy—representing each euro area country—is calibrated using country-specific housing and mortgage market moments, holding all remaining parameters constant across countries.

This heterogeneity closely parallels the empirical patterns documented in Section 2: countries with higher ARM shares, higher homeownership rates, and higher LTV ratios tend to exhibit stronger reactions. Figure 6b compares the empirical differential responses—reported in the right panels of Figures 2 and 3, aggregated to quarterly frequency—with their model

Figure 6: Heterogeneous transmission to a common euro area monetary policy shock

(a) Impulse responses across countries
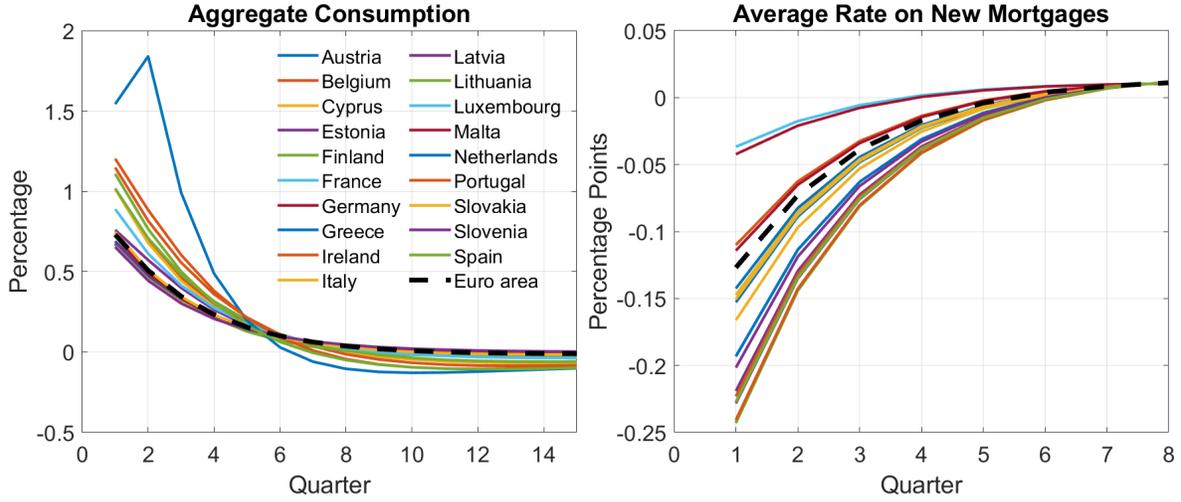
(b) Relative impulse response of high versus low values of housing and mortgage market characteristics
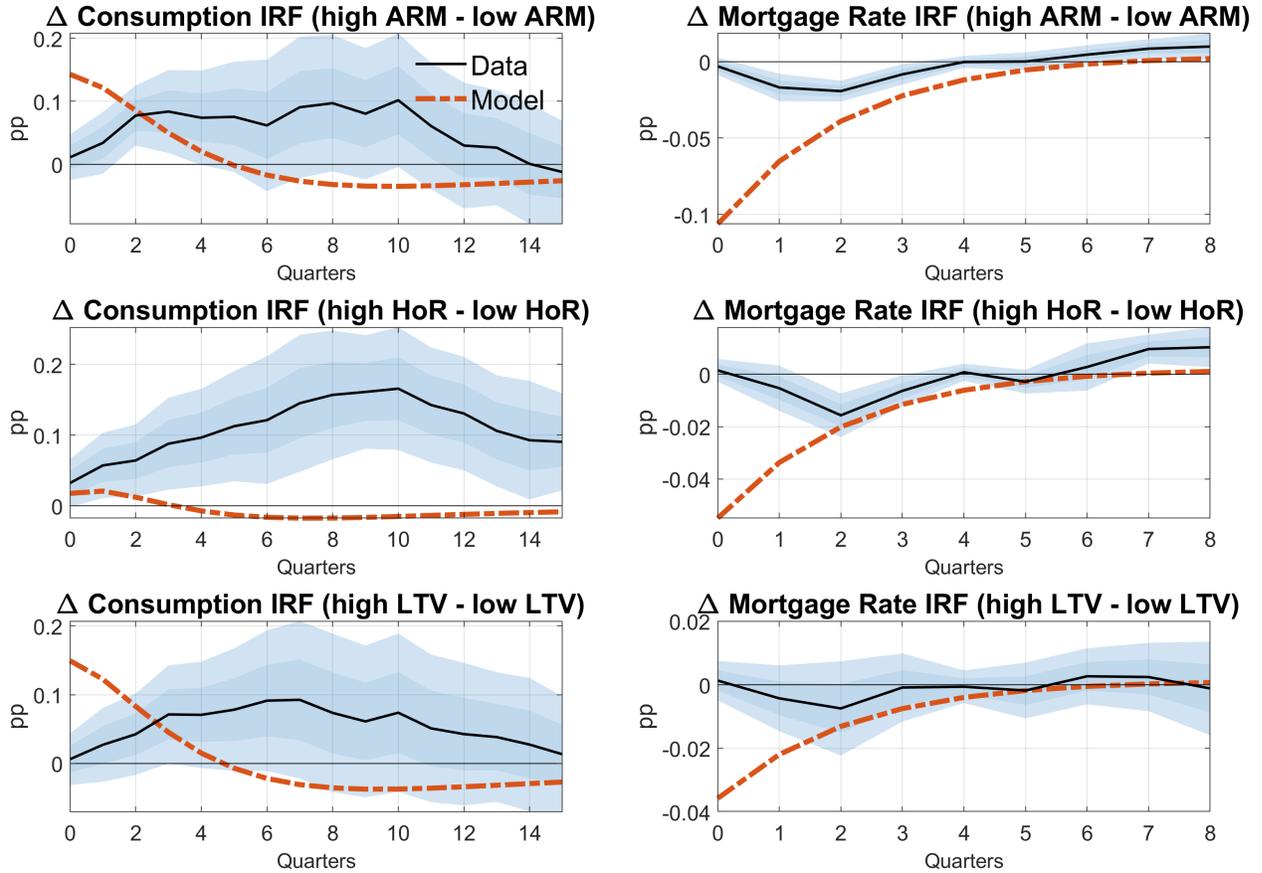
Note: The figure shows model-based impulse response functions of aggregate consumption and mortgage interest rates following a one-time shock ϵ_t in the Taylor rule (7), normalized to a 25 basis point fall in the nominal interest rate on impact. The bottom panel plots empirical and model-based differential responses of high versus low values of housing and mortgage market characteristics.

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counterparts.[19] The model reproduces well the relatively stronger consumption and mortgage-rate responses associated with these institutional features. As discussed in Section 3.3, the empirical impulse responses are more persistent, reflecting propagation mechanisms abstracted from in the model but immaterial for the results that follow. In contrast to consumption, the model-implied mortgage-rate pass-through is somewhat stronger than in the data, particularly for the ARM share, indicating that the model tends to overstate the quantitative pass-through in countries with high housing and mortgage market values relative to those with low values.

4.2 Decomposing the effects of ARM shares, HoR, and LTV

Having shown that country-specific housing and mortgage market features generate substantial heterogeneity in monetary-policy transmission, I next assess which characteristics are most influential in driving these differences. To do so, I compare Portugal (PT)—which lies above the euro-area median in all three dimensions (ARM share 95%, HoR 78%, LTV 0.92; Table 2)—with the euro area (EA) as a whole.

Figure 7a shows that PT (red solid line) responds more strongly to the monetary policy shock than the EA benchmark (blue solid line with dots). The high prevalence of adjustable-rate mortgages in PT leads to a stronger pass-through from policy rates to mortgage interest rates, lowering debt service costs more sharply and amplifying the cash-flow channel. The steeper fall in new mortgage rates also boosts borrowing, reinforcing the mortgage credit channel—an effect further enhanced by PT's higher maximum LTV ratio. In addition, a higher HoR increases the share of high-marginal-propensity-to-consume borrowers benefiting from easier credit. Combined, these mechanisms produce a much stronger aggregate consumption response in PT than in the EA.

To assess the contribution of each structural feature, Figure 7a also reports EA responses under three counterfactual calibrations in which the ARM share, HoR, or LTV is individually set to the higher PT's value. Four key findings emerge. First, consistent with the discussion in Section 3.2.1, the pass-through from nominal interest rates to both outstanding and newly issued mortgage rates is driven entirely by the ARM share. Second, the rise in newly originated mortgages remains modest across all counterfactuals relative to the EA benchmark. Third, while higher ARM shares and higher LTV ratios in isolation exert only limited effects on aggregate consumption, a higher HoR substantially increases the consumption response, raising its peak by 35 basis points—compared with the 47-basis-point gap between PT and

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[19]In the model, I compute the difference between the average impulse responses of countries with higher values of the relevant housing and mortgage market characteristics and those with lower values, yielding the model analogue of the estimated $\hat{\gamma}$ in equation (1). For consumption, I exclude the Netherlands, which combines a relatively low homeownership rate with an exceptionally high median LTV of 100%, producing the outsized model response shown in Figure 6a.

Figure 7: Impulse response functions to a monetary policy shock: euro area vs. Portugal

(a) Comparison between euro area, Portugal, and three separate counterfactuals
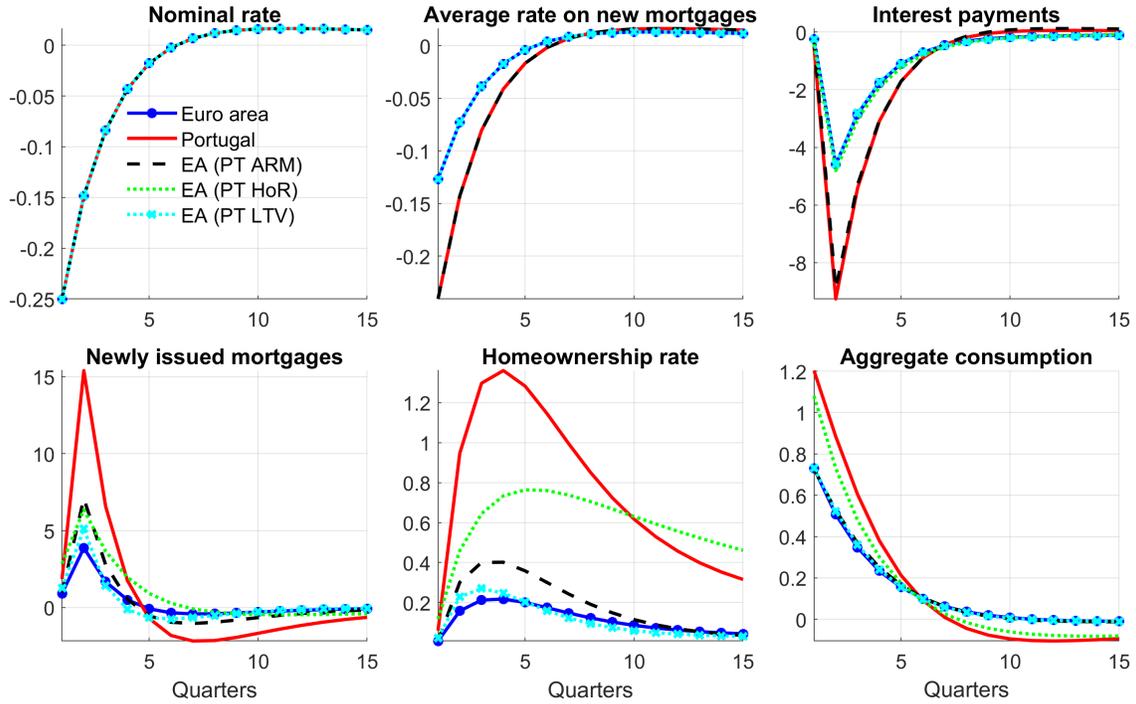
(b) Comparison between euro area, Portugal, and the sum of counterfactuals
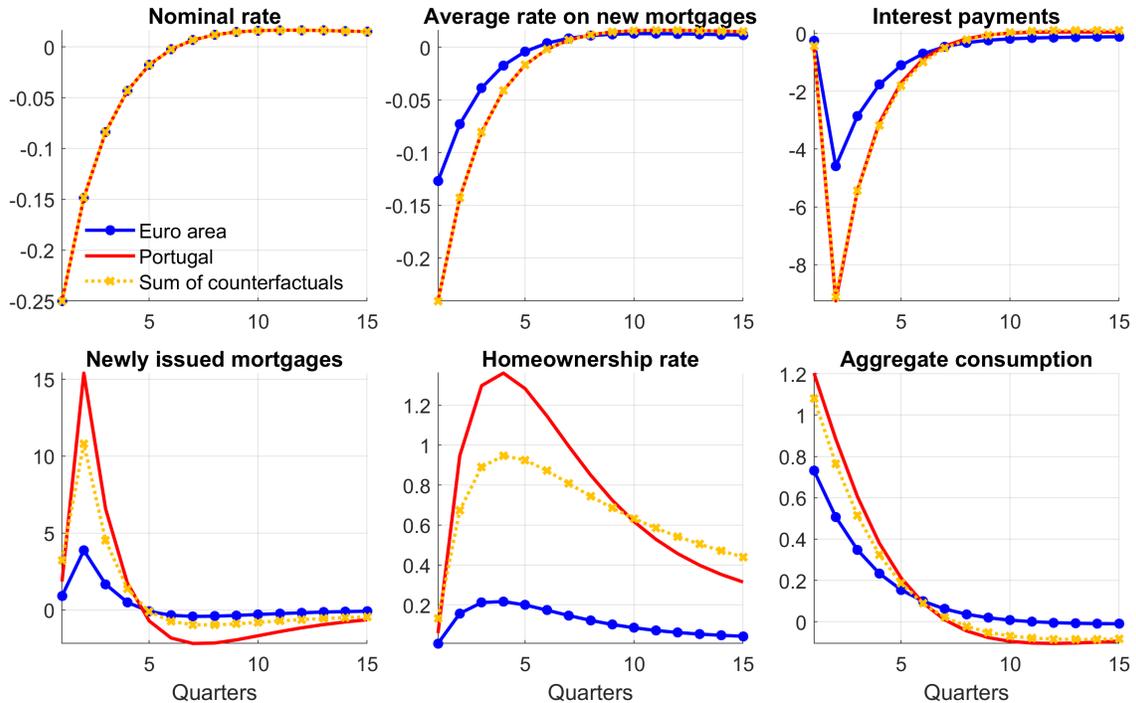
Note: Model-based impulse responses to a one-time shock ϵ_t in the Taylor rule (7), normalized to a 25 basis point fall in the nominal interest rate on impact. The y-axis measures a 1% deviation from steady state, except for interest rates, which are measured in percentage points. Counterfactual economies include the EA recalibrated to PT's ARM share ("EA (PT ARM)"), PT's homeownership rate ("EA (PT HoR)"), and PT's LTV ratio ("EA (PT LTV)"). "Sum of counterfactuals" sums the difference in response of each counterfactual economy relative to the EA.

the EA baseline. However, no single housing or mortgage market characteristic can by itself account for the full difference between PT and EA responses.

Figure 7b further shows that the PT consumption response exceeds the sum of the deviations implied by increasing each characteristic individually ("Sum of counterfactuals"). This indicates that an economy featuring simultaneously high ARM share, high HoR, and high LTV ratio—such as PT—responds more strongly than what a linear decomposition would suggest. Even though the model is solved to first order, interactions among these structural features generate meaningful nonlinear amplification: high ARM shares, high HoR, and high LTVs reinforce each other in strengthening the transmission of monetary policy to aggregate consumption.

To shed light on the mechanisms behind these amplification effects, Figure 8a reports household-level impulse responses that underlie the aggregate dynamics. The stronger aggregate response in PT is driven mainly by the pronounced and persistent reaction of mortgaged homeowners—wealthy hand-to-mouth households who consume out of borrowing capacity and are more prevalent in PT than in the EA, leading to higher aggregate MPC as discussed in Section 3.3.3.[20] The amplification in aggregate consumption thus reflects a magnified response of mortgaged homeowners.

Two mechanisms are at work. First, PT's higher HoR implies that, in steady state, a larger share of the housing stock is held by borrowers, enabling them to expand borrowing more strongly during an expansion for a given house price response. Second, higher LTV ratios and a higher ARM share by themselves boost mortgaged-homeowner consumption only modestly relative to the EA baseline. However, when these features operate in an economy with a larger mass of mortgaged homeowners, their effects compound: more borrowers are able to increase leverage through higher LTVs and benefit from lower mortgage payments, raising their MPC even further. The resulting amplification in mortgaged-homeowner consumption translates directly into a stronger aggregate response.

Taken together, these heterogeneous household-level reactions explain why the combination of high ARM share, high HoR, and high LTV ratio in PT generates substantially larger aggregate effects than in the EA as a whole.

4.3   Mortgage credit, homeownership rate, and cash-flow channels

Building on the previous analysis, I next assess the contribution of housing and mortgage market channels to the heterogeneous transmission of monetary policy across the euro area.

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[20]Renters initially raise consumption through higher labor income, but as many transition into mortgaged homeownership—consistent with the increase in HoR shown in Figure 7a—their consumption falls sharply. Savers reduce consumption to supply mortgage credit to impatient borrowers.

Figure 8: Consumption impulse responses to a monetary policy shock, euro area vs. Portugal

(a) Comparison between euro area, Portugal, and three separate counterfactuals
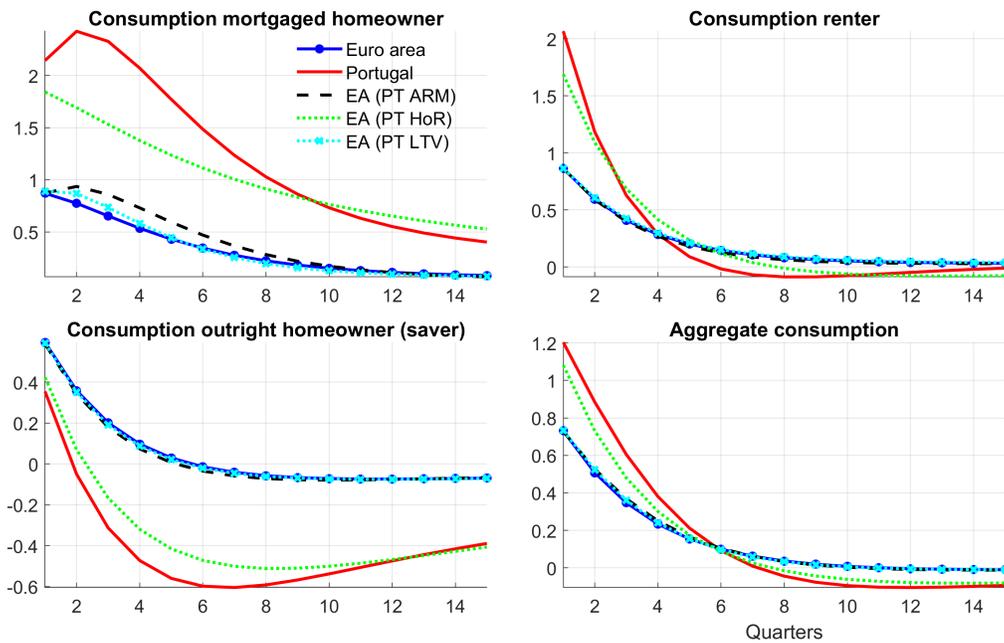
(b) Comparison between euro area, Portugal, and the sum of counterfactuals
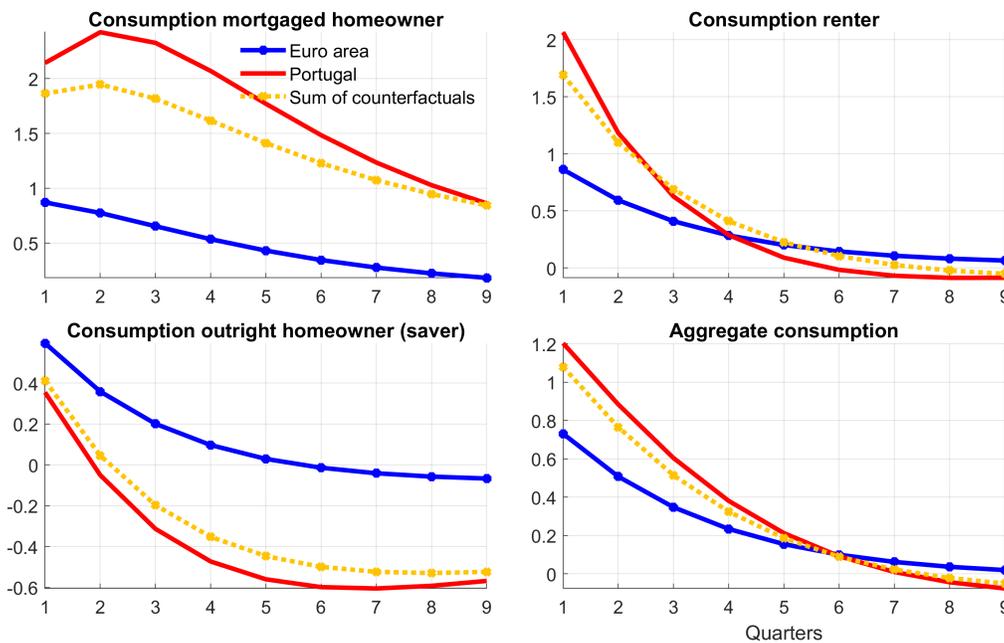
Note: Model-based impulse responses to a one-time shock ϵ_t in the Taylor rule (7), normalized to a 25 basis point fall in the nominal interest rate on impact. The y-axes measure a 1% deviation relative to steady state. Counterfactual economies include the EA recalibrated to PT's ARM share ("EA (PT ARM)"), PT's homeownership rate ("EA (PT HoR)"), and PT's LTV ratio ("EA (PT LTV)"). "Sum of counterfactuals"sums the difference in response of each counterfactual economy relative to the EA.

Figure 9: Impulse responses to a monetary policy shock and housing and mortgage channels
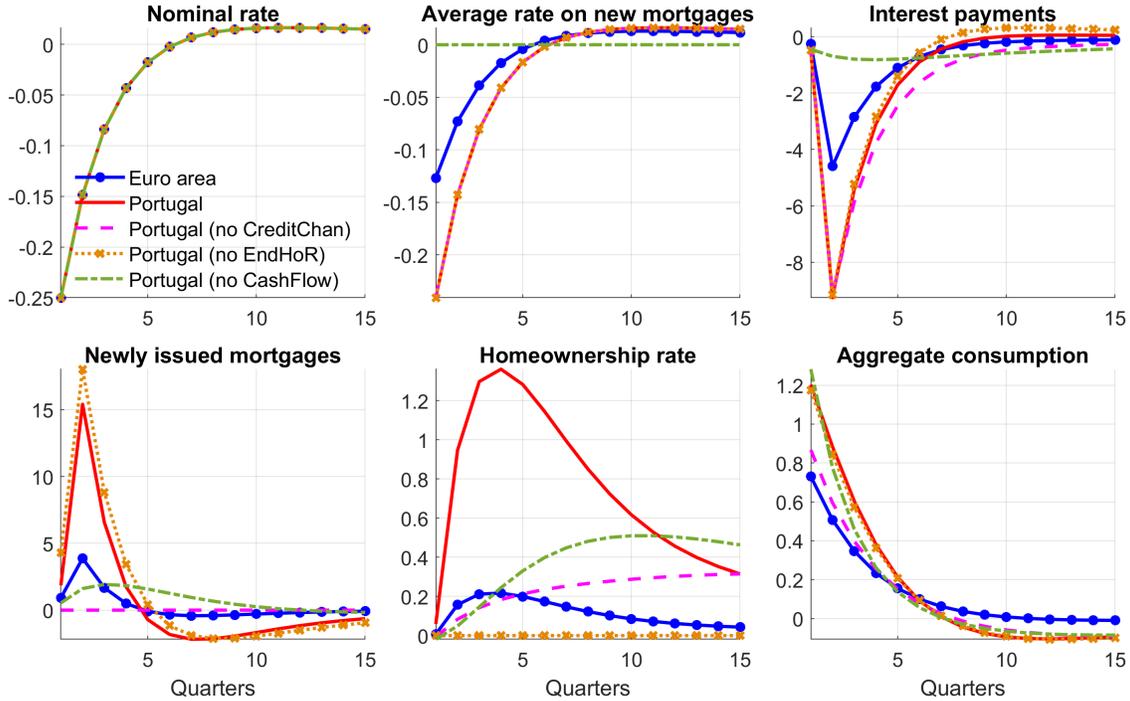
Note: Model-based impulse responses to a one-time shock ϵ_t in the Taylor rule (7), normalized to a 25 basis point fall in the nominal interest rate on impact. The y-axes measure a 1% deviation relative to steady state, except for interest rates, which are measured in percentage points. Counterfactuals include PT with steady-state newly issued mortgages ("Portugal (no CreditChan)"), steady-state homeownership rate ("Portugal (no EndHoR)"), and steady-state mortgage interest rates ("Portugal (no CashFlow)").

Starting from the PT benchmark economy—with its high ARM share, HoR, and LTV—I construct a sequence of counterfactuals in which a single economic channel is switched off, to quantify its role in the difference between PT and EA responses.

Figure 9 shows results for three such counterfactuals alongside the baseline PT and EA responses. In the first, I shut down the *mortgage credit channel* by fixing newly issued mortgages $m_{b,t}$ from equation (3) at their steady-state level. Without this channel, borrowers cannot translate lower mortgage interest expenses into higher debt, reducing resources for high-MPC households and bringing aggregate consumption close to the EA level.

The second counterfactual removes the *homeownership rate channel* by fixing HoR at its steady-state value. While this redistribution allows renters to consume more—since they cannot demand housing to become homeowners—it has little effect on aggregate consumption, consistent with Dias and João B. Duarte (2022), who find similar results for the U.S.

The third counterfactual shuts down the *cash-flow channel* by keeping mortgage interest rates constant. Although lower nominal rates still affect the economy via the saver Euler equation and price movements, mortgaged homeowners see only a small reduction in debt

Table 3: Difference in peak consumption responses at different LTV ratios

LTV in Portugal	0.90	0.80	0.70	0.60	0.50	0.40	0.30	0.20
Consumption difference PT-EA	45	32	23	16	11	6	2	-2

Note: The table reports the difference in basis points between the peak consumption impulse responses in Portugal and the euro area for different LTV ratios applied to Portugal.

service costs (via inflation), limiting their ability to expand housing and take on more debt. Renters and savers consume more initially, but aggregate consumption quickly falls back, highlighting that the cash-flow channel mainly builds persistence through the gradual decline in mortgage interest payments.

In sum, among the channels originating in the housing and mortgage markets, the mortgage credit channel is the most powerful driver of economic activity and a key source of cross-country heterogeneity in monetary policy transmission.

4.4 LTV as macroprudential policy

The preceding analysis has shown that cross-country differences in housing and mortgage market structures—particularly the ARM share, HoR, and LTV ratios—generate substantial heterogeneity in the transmission of monetary policy within the euro area. Since uniform transmission remains a central policy objective (Cœuré (2019)), it is natural to ask which policy levers might narrow these differences in practice.

Although a euro-area banking union formally exists, its effective scope is still limited (Garicano (2019)), leaving most macroprudential instruments under national control. Among these, the regulation of LTV ratios is one of the few tools that directly affects a structural parameter highlighted in Section 4.2. It is important to emphasize, however, that LTV limits are not designed to influence the transmission of monetary policy. Their practical purpose is to contain household indebtedness and to mitigate systemic risk. Nonetheless, the sizeable variation in LTV ratios documented in Table 2 suggests that, in principle, a coordinated approach could alter the degree of heterogeneity.

Table 3 quantifies how lowering Portugal's LTV ratio affects the difference in peak consumption responses between Portugal and the euro-area benchmark. Fully eliminating this gap would require reducing Portugal's LTV to roughly 0.3—around one-third of its current level. Such a drastic adjustment underscores that, within plausible policy bounds, LTV regulation has only limited capacity to materially reduce monetary-policy heterogeneity.

Other measures would therefore be necessary. A gradual reduction in ARM prevalence,

for example, would weaken the cash-flow channel, though this margin is determined largely by bank lending practices rather than direct policy intervention.[21] Greenwald (2018) also shows that capping payment-to-income ratios—while not modeled here—can effectively dampen boom–bust dynamics. Overall, a broader policy strategy that combines macroprudential regulation with incentives for greater mortgage-market diversification is likely to be more effective in promoting convergence in monetary-policy transmission across the euro area.

5 Conclusion

This paper shows that cross-country differences in the adjustable-rate mortgage (ARM) share, homeownership rate (HoR), and loan-to-value (LTV) ratio—three positively correlated housing and mortgage market institutions—are central to explaining the heterogeneous transmission of monetary policy in the euro area. Using new empirical evidence and a calibrated two-country currency-union model, I find that these features amplify one another through the mortgage credit, cash-flow, and homeownership rate channels, with the mortgage credit channel playing the dominant role.

Policy experiments indicate that lowering high LTV ratios can mitigate heterogeneity but that this instrument alone is insufficient; harmonizing ARM shares and HoRs—for example through rental market reforms or targeted subsidies—would further align transmission across member states. Other structural differences, such as cross-country variation in wage rigidities (Corsetti, Joao B Duarte, and Mann 2021), may also matter and warrant further research.

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[21]In a previous draft (Pica (2021)), I considered a euro-area-wide mortgage market with more uniform issuance of contract types, showing that such harmonization can mitigate monetary-policy heterogeneity.

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Appendix A Additional results

While the baseline analysis in the paper relies on the panel specification (1), I also estimate country-specific responses of the relevant variables using local projection methods, following the approach in Almgren et al. (2022). In contrast to the baseline specification, this approach does not control for country fixed effects and instead estimates a separate time series regression for each country. Specifically, for each country c and each horizon $h = 0, \ldots, H$, I estimate the following equation:

$$y_{t+h}^c - y_{t-1}^c = \alpha_h^c + \beta_h^c \epsilon_t^{MP} + \sum_{k=1}^{K} \omega_{k,h}^c X_{t-k}^c + u_{t,h}^c \tag{A.1}$$

where y is the variable of interest, ϵ_t^{MP} is the monetary policy shock, and X denotes the same set of control variables used in specification (1).

To more transparently illustrate the dynamic effects of the identified monetary policy surprises discussed in Section 2.1, I apply specification (A.1) to the short-term interest rate (Eonia) and selected euro area aggregates. I normalize the shock such that the short rate declines by 25 basis points on impact, and use this normalization to scale all impulse responses—both in this section and in the panel specification (1). Figure A.1 shows that the shock leads to a persistent decline in the short rate, reaching a trough of approximately 1 percentage point after six months. Mortgage rates exhibit a similar trajectory, although the magnitude of the response is roughly half that of the short rate. In contrast, aggregate consumption and the outstanding mortgage stock display more persistent responses.

Figure A.2 displays the impulse responses of aggregate consumption in each euro area country to a monetary policy shock normalized to reduce the short rate by 25 basis points on impact. While the initial effects are generally modest, the peak responses tend to occur after approximately two years. The responses reveal substantial heterogeneity across euro area countries, consistent with earlier findings in the literature, including Calza, Monacelli, and Stracca (2013), Corsetti, Joao B Duarte, and Mann (2021), and Almgren et al. (2022).

Figure A.3 reports the corresponding impulse responses of average interest rates on new mortgage loans. Similar to consumption, these responses display substantial cross-country heterogeneity.

Appendix B Model derivations and solution

This appendix is organized as follows. Section B.1 lists the optimality conditions of the agents of the model economy. I define the wage Phillips curve in Section B.2, and the main

Figure A.1: Impulse responses of euro area variables to an expansionary monetary shock
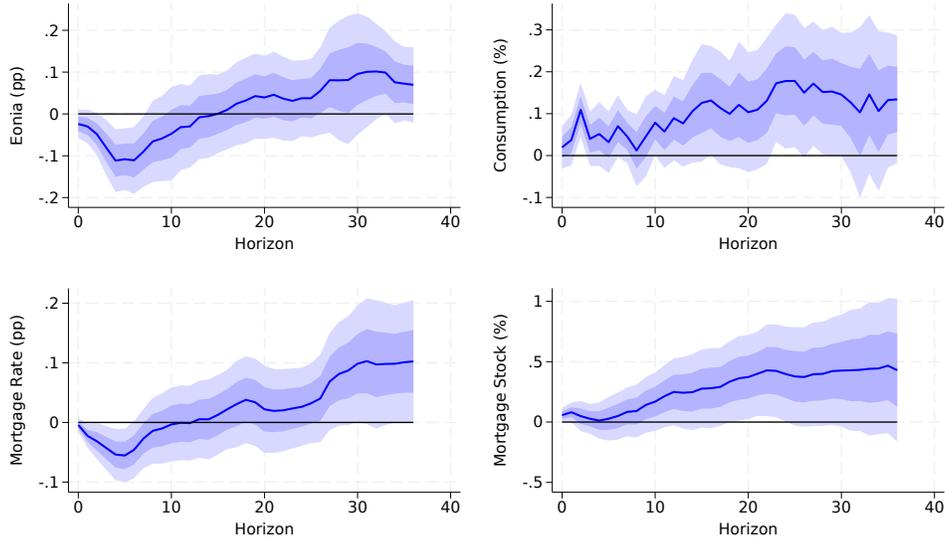
Note: The figure shows impulse responses of euro area variables to an expansionary monetary surprise of one standard deviation. The response is estimated using equation (A.1), with Newey-West standard errors. The 95% and 68% confidence intervals are shown in light and dark blue, respectively. The estimation sample spans 2000M1–2012M12.

equations of the Home-Foreign structure in Section B.3.

B.1   Optimality Conditions

B.1.1   Borrower Solution

Optimality with respect to housing services implies that the rental price equals the marginal rate of substitution between housing services and consumption:
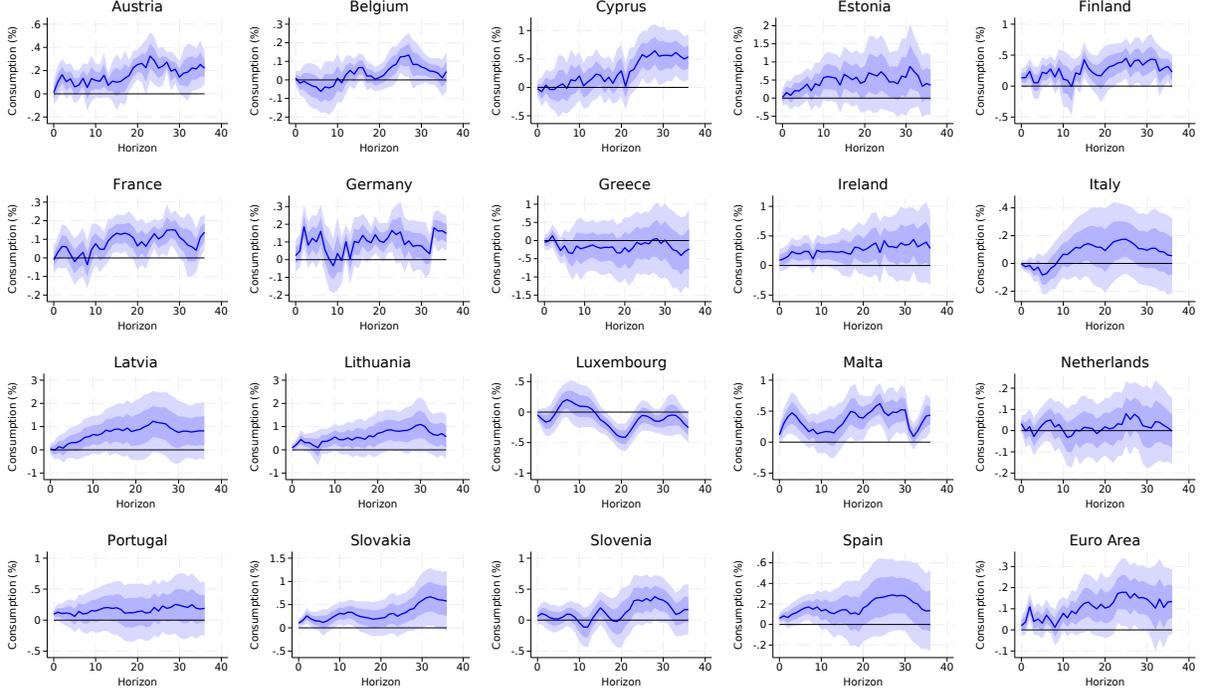
$$p_{r,t} = \frac{u_{b,t}^h}{u_{b,t}^c} \tag{B.1}$$

Optimality with respect to new mortgages reads as:

$$\mu_t + \Omega_{b,t}^m + q_t \Omega_{b,t}^x = 1 \tag{B.2}$$

where μ_t is the multiplier on the LTV constraint. $\Omega_{b,t}^m$ and $\Omega_{b,t}^x$ are, respectively, the marginal continuation costs to the borrower of taking an additional euro of face value debt, and of

Figure A.2: Impulse responses of aggregate consumption to an expansionary monetary shock

Note: The figure shows impulse responses of aggregate consumption to an expansionary monetary surprise of one standard deviation. For each country, the response is estimated using equation (A.1), with Newey-West standard errors. The 95% and 68% confidence intervals are shown in light and dark blue, respectively. The estimation sample spans from 2000M1 to 2012M12.

promising an additional euro of initial payments:

$$\Omega_{b,t}^m = E_t \Lambda_{t,t+1}^b \pi_{t+1}^{-1}[(1-\tau)(1-\alpha)q_t + \rho(1-\nu) + \nu + (1-\rho)(1-\nu)\Omega_{b,t+1}^m] \tag{B.3}$$

$$\Omega_{b,t}^x = E_t \Lambda_{t,t+1}^b \pi_{t+1}^{-1}[(1-\tau)\alpha + (1-\rho)(1-\nu)\Omega_{b,t+1}^x] \tag{B.4}$$

where $\Lambda_{t,t+1}^b = \beta_b \frac{u_{b,t+1}^c}{u_{b,t}^c}$ is the borrower stochastic discount factor.

Furthermore, the borrowers optimize with respect to new house size:

$$p_t^h = \frac{\mathbb{E}_t \Lambda_{t,t+1}^b \{p_{r,t+1} + \bar{\omega}_{b,t} + p_{h,t+1}[(1-\delta) - (1-\rho)\mathcal{C}_{t+1}]\}}{1 - \mathcal{C}_t}. \tag{B.5}$$

where $\mathcal{C}_t \equiv \mu_t \theta_{LTV}$ is the marginal collateral of housing, representing the benefit to the borrowers from investing into housing thus relaxing the LTV constraint. Equation (B.5) states that the marginal benefits from investing one more euro in housing includes the foregone rental cost next period $p_{r,t+1}$, the utility benefit from owning $\bar{\omega}_{b,t}$ as in Greenwald and Guren (2021), and the housing value next period.

Figure A.3: Impulse responses of mortgage interest rates to an expansionary monetary shock
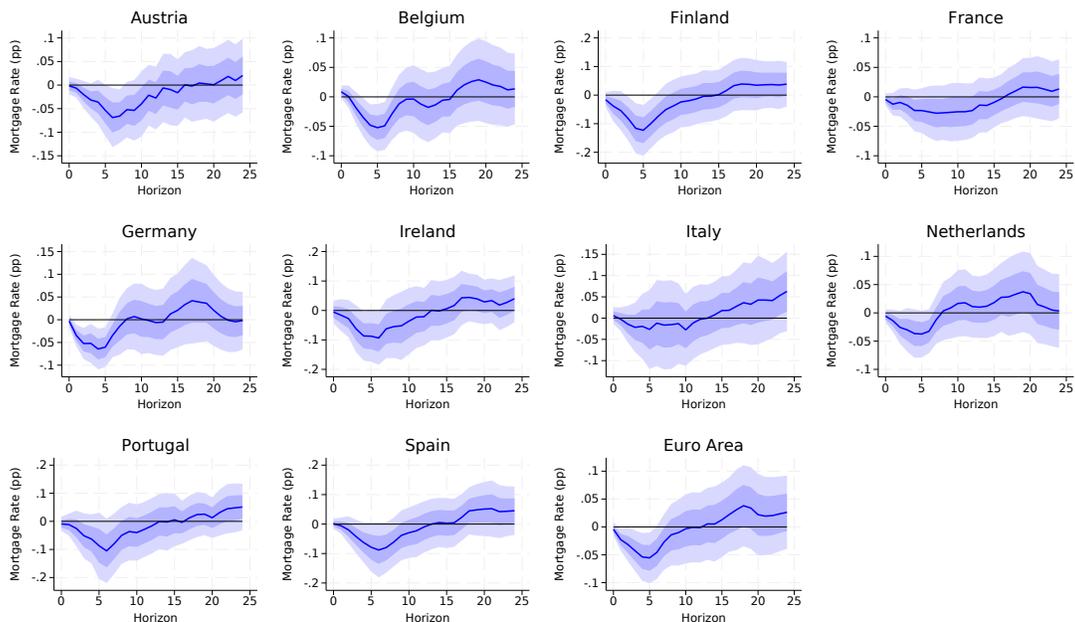
Note: The figure shows impulse responses of average mortgage interest rates on new loans to an expansionary monetary surprise of one standard deviation. For each country, the response is estimated using equation (A.1), with Newey-West standard errors. The 95% and 68% confidence intervals are shown in light and dark blue, respectively. The estimation sample spans from 2000M1 to 2012M12.

Finally, the relevant normalization for the ownership utility term in the borrower budget constraint is: $A_{b,t} = \frac{(H_{b,t}+H_{l,t})^2}{H_{l,t}}$.

B.1.2 Saver Solution

Savers can invest in one-period nominal bonds, and the corresponding Euler equation is:

$$E_t \left[\Lambda^s_{t,t+1} \pi^{-1}_{t+1} R_t \right] = 1 \tag{B.6}$$

The optimality with respect to house size, which I only use in the calibration to set the saver housing demand $h_{s,t}$ to its steady-state value, implies:

$$p_{h,t} = \frac{u^h_{s,t}}{u^c_{s,t}} + E_t \left[\Lambda^s_{t,t+1} p_{h,t+1}(1-\delta) \right] \tag{B.7}$$

Turning to the mortgage market optimality condition, in Section 3.2 I show the optimality condition of the savers with respect to newly issued mortgages, equation (8). I here define the auxiliary terms. First, let $\Omega^m_{s,t}$ denote the marginal continuation value to savers of an

additional euro of newly issued mortgage debt:

$$\Omega^m_{s,t} = E_t \Lambda^s_{t,t+1} \pi^{-1}_{t+1}[(1-\alpha)q^A_t + \rho(1-\nu) + \nu + (1-\rho)(1-\nu)\Omega^m_{s,t+1}] \tag{B.8}$$

where $\Lambda^s_{t,t+1} = \beta_s \frac{u^c_{s,t+1}}{u^c_{s,t}}$ is the stochastic discount factor of savers, with $u^c_{s,t}$ denoting their marginal utility of consumption at time t. The continuation value in equation (B.8) reflects the present value of: a) interest payments on the ARM share, $(1-\alpha)q^A_t$; b) the principal amortization ν; and c) the full net repayment $(1-\nu)$ in states where borrowers refinance (with probability ρ). If borrowers do not refinance (with probability $1-\rho$), these returns continue to accrue in future periods.

Second, define $\Omega^x_{s,t}$ as the marginal continuation value of an additional euro of promised payments on fixed-rate mortgages:

$$\Omega^x_{s,t} = E_t \Lambda^s_{t,t+1} \pi^{-1}_{t+1}[\alpha + (1-\rho)(1-\nu)\Omega^x_{s,t+1}] \tag{B.9}$$

This captures the value of receiving the FRM component α in states where borrowers do not refinance.

B.1.3 Landlord Solution

The landlords only optimize with respect to new house size, leading to:

$$p_{h,t} = E_t \Lambda^s_{t,t+1}[p_{r,t+1} + \bar{\omega}_{l,t} + p_{h,t+1}(1-\delta)] \tag{B.10}$$

where the relevant normalization for the ownership utility term in the landlord budget constraint is: $A_{l,t} = \frac{(H_{b,t}+H_{l,t})^2}{H_{b,t}}$.

B.1.4 Transmission to interest rate on ARMs

A feature of the model is that the interest rate on adjustable-rate mortgages $q^A_t + 1$ is set to be equal to the nominal interest rate R_t. To see why this makes sense, consider the case in which all mortgages are adjustable-rate, i.e., $\alpha = 0$. It is easy to show that the saver's optimality condition for newly issued mortgages (8) reduces to: $E_t[\Lambda^s_{t,t+1}\pi^{-1}_{t+1}(q^A_t + 1)] = 1$.

Comparing the previous equation with the saver Euler equation (B.6) yields $R_t = q^A_t + 1$. Intuitively, this no-arbitrage condition ensures that savers are indifferent between investing one euro in a bond—yielding R_t in the next period—and issuing one euro in new ARMs—yielding $q^A_t + 1$. I impose this equilibrium condition even when the economy features a positive fixed-rate mortgage share ($\alpha > 0$). This assumption is also empirically motivated: in euro

area countries, ARM interest rates are typically indexed to the ECB's policy rate, such as the Eonia.

B.1.5 Transmission to interest rate on FRMs

Consider now an economy in which all mortgages are fixed-rate, i.e., $\alpha = 1$. In this case, the continuation value equations (B.8) and (B.9) reduce to those studied by Greenwald (2018), who applies them to analyze mortgage debt dynamics in the United States, while the first order condition on newly issued mortgage loans is still defined by equation (8). Savers lock-in q_t^F for the whole duration of the mortgage contract and, by the expectations hypothesis, the fixed rate q_t^F moves more slowly than the nominal interest rate in equilibrium.[22]

The extent of the pass-through depends on the refinancing probability ρ, the fraction of principal paid ν, and the inflation-adjusted stochastic discount factor $\Lambda_{t,t+1}^s \pi_{t+1}^{-1}$.[23] The latter component is the same across countries (i.e., $\Lambda_{t,t+1}^s \pi_{t+1}^{-1} = \Lambda_{t,t+1}^{*,s} \pi_{t+1}^{*,-1}$), because the Euler equation (B.6) holds in each country and the nominal interest rates are the same ($R_t = R_t^*$). In the calibration of Section 3.3, I assume $\rho = \rho^*$ and $\nu = \nu^*$ given the lack of microdata which would allow me to estimate them separately. Therefore, the pass-through from the nominal rates to the mortgage interest rate on FRMs is exactly the same across countries, that is $q_t^F = q_t^{*,F}$.

B.2 The Labor Market and The Wage Phillips Curve

In deriving the wage Phillips curve, I follow Auclert, Rognlie, and Straub (2018) and extend their result to households with different discount factors.

Each household i provides hours of work n_{ikt} to a continuum of unions indexed by $k \in [0, 1]$. Therefore, household i provides a total of $n_{it} \equiv \int_k n_{ikt} dk$ hours of work. Unions aggregate hours of work into tasks: $N_{kt} = \int n_{ikt} di$. A competitive labor packer packages these tasks into aggregate labor demand using the technology: $N_t = \left(\int_k N_{kt}^{\frac{\varphi-1}{\varphi}} dk \right)^{\frac{\varphi}{\varphi-1}}$ and sell these services to perfectly competitive producers in the final good sector at price W_t.

Next, each union k that adjusts the nominal wage W_{kt} determines a quadratic utility cost to households. Specifically, each household utility (2) features an additive cost $\frac{\psi}{2} \int_k \left(\frac{W_{kt}}{W_{kt-1}} - 1 \right)^2 dk$. In a symmetric equilibrium, unions set equal wages and ask households to supply the same hours of labor, implying $\frac{N_{b,t}}{\chi_b} = \frac{N_{s,t}}{\chi_s} = N_t$.

---

[22]Guren, Krishnamurthy, and McQuade (2021) also formalize this idea in a quantitative life-cycle model and show that, because of the stronger pass-through to mortgage rates, ARMs are better suited than FRMs to stabilize a housing crisis.

[23]In particular, a higher refinancing rate ρ or a higher fraction of principal paid each period ν imply a stronger equilibrium pass-through because q_t^F is locked-in for a smaller period of time.

Finally, I follow the derivation in Auclert, Rognlie, and Straub (2018) and show that in my setting the wage Phillips curve takes the form in equation (4).

B.3 The Home-Foreign Structure

The world economy has unitary measure, with Home having measure n and Foreign $(1-n)$. The Home-Foreign structure closely follows Faia and Monacelli (2008) with some adjustment related to housing expenditures.

Aggregate consumption in the Home economy (which includes non-durables as well as expenditures on housing) is described by the following index of domestic and imported bundles of goods:

$$AC_t \equiv \left[(1-\gamma)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}},$$

where $\eta > 0$ is the elasticity of substitution between domestic and foreign goods, and $\gamma \equiv (1-n)\lambda$ denotes the weight of imported goods in the Home consumption. This weight depends on $(1-n)$, the relative size of Home, and on λ, the degree of trade openness of Home. Analogously, consumption preferences in Foreign are defined as:

$$AC_t^* \equiv \left[(1-\gamma^*)^{\frac{1}{\eta}} C_{F,t}^{*\frac{\eta-1}{\eta}} + \gamma^{*\frac{1}{\eta}} C_{H,t}^{*\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}.$$

where $\gamma^* \equiv n\lambda^*$. Each consumption bundle $C_{H,t}$ and $C_{F,t}$ is composed of imperfectly substitutable varieties:

$$C_{H,t} \equiv \left[\left(\frac{1}{n}\right)^{\frac{1}{\epsilon}} \int_0^n C_{H,t}(i)^{\frac{\epsilon-1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}}; \quad C_{F,t} \equiv \left[\left(\frac{1}{1-n}\right)^{\frac{1}{\epsilon}} \int_n^1 C_{F,t}(i)^{\frac{\epsilon-1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}};$$

$$C_{H,t}^* \equiv \left[\left(\frac{1}{n}\right)^{\frac{1}{\epsilon}} \int_0^n C_{H,t}^*(i)^{\frac{\epsilon-1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}}; \quad C_{F,t}^* \equiv \left[\left(\frac{1}{1-n}\right)^{\frac{1}{\epsilon}} \int_n^1 C_{F,t}^*(i)^{\frac{\epsilon-1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}}.$$

where $\epsilon > 1$ is the elasticity of substitution across the differentiated products.

The consumption-based price indices that correspond to the above specifications of preferences are given by:

$$P_t = \left[(1-\gamma)P_{H,t}^{1-\eta} + \gamma P_{F,t}^{1-\eta} \right]^{\frac{1}{1-\eta}}; \quad P_t^* = \left[(1-\gamma^*)P_{F,t}^{*1-\eta} + \gamma^* P_{H,t}^{*1-\eta} \right]^{\frac{1}{1-\eta}}.$$

$P_{H,t}$ is the price sub-index for home-produced goods expressed in the domestic currency, $P_{F,t}$ is the price sub-index for foreign-produced goods expressed in the domestic currency, $P_{H,t}^*$ is the price sub-index for home-produced goods expressed in the foreign currency, and $P_{F,t}^*$ is the price sub-index for foreign-produced goods expressed in the foreign currency. The price

sub-indices are defined as follows:

$$P_{H,t} = \left[\left(\frac{1}{n}\right)\int_0^n P_{H,t}(i)^{1-\epsilon}di\right]^{\frac{1}{1-\epsilon}} ; \quad P_{F,t} = \left[\left(\frac{1}{1-n}\right)\int_n^1 P_{F,t}(i)^{1-\epsilon}di\right]^{\frac{1}{1-\epsilon}} ;$$

$$P_{H,t}^* = \left[\left(\frac{1}{n}\right)\int_0^n P_{H,t}^*(i)^{1-\epsilon}di\right]^{\frac{1}{1-\epsilon}} ; \quad P_{F,t}^* = \left[\left(\frac{1}{1-n}\right)\int_n^1 P_{F,t}^*(i)^{1-\epsilon}di\right]^{\frac{1}{1-\epsilon}} .$$

For notational convenience, I impose the goods-market clearing conditions of each country: $AC_t \equiv C_t + \delta p_t^h \bar{H} = Y_t$; $AC_t^* \equiv C_t^* + \delta p_t^{*,h} \bar{H}^* = Y_t^*$. We can additionally express the consumption bundles $C_{H,t}$ and $C_{F,t}$ as function of aggregate country-level output:

$$C_{H,t} = \left(\frac{P_{H,t}}{P_t}\right)^{-\eta}(1-\gamma)Y_t; \quad C_{F,t} = \left(\frac{P_{F,t}}{P_t}\right)^{-\eta}\gamma Y_t;$$

$$C_{H,t}^* = \left(\frac{P_{H,t}^*}{P_t^*}\right)^{-\eta}\gamma^* Y_t^*; \quad C_{F,t}^* = \left(\frac{P_{F,t}^*}{P_t^*}\right)^{-\eta}(1-\gamma^*)Y_t^*;$$

Finally, we can derive the intermediate good-level demand of each consumption bundle:

$$C_{H,t}(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\epsilon}\left(\frac{1}{n}\right)C_{H,t}; \quad C_{F,t}(i) = \left(\frac{P_{F,t}(i)}{P_{F,t}}\right)^{-\epsilon}\left(\frac{1}{1-n}\right)C_{F,t};$$

$$C_{H,t}^*(i) = \left(\frac{P_{H,t}^*(i)}{P_{H,t}^*}\right)^{-\epsilon}\left(\frac{1}{n}\right)C_{H,t}^*; \quad C_{F,t}^*(i) = \left(\frac{P_{F,t}^*(i)}{P_{F,t}^*}\right)^{-\epsilon}\left(\frac{1}{1-n}\right)C_{F,t}^*;$$

Law of one price. I assume that the law of one price holds, meaning that $P_{H,t}(i) = \zeta_t P_{H,t}^*(i)$ and $P_{F,t}(i) = \zeta_t P_{F,t}^*(i)$, where ζ_t is the nominal exchange rate. Notice that by plugging the previous expressions into the corresponding price-subindices formulae, we can derive that $P_{H,t} = \zeta_t P_{H,t}^*$ and $P_{F,t} = \zeta_t P_{F,t}^*$. That is, the law of one price also holds at the price of the consumption bundles. However, given the presence of home bias, purchasing power parity does not hold, that is, $P_t \neq \zeta_t P_t^*$. Hence, I denote the real exchange rate as $Q_t \equiv \frac{\zeta_t P_t^*}{P_t}$.

Total variety demands. Market clearing for domestic variety i must satisfy:

$$\begin{aligned} Y_t(i) &= nC_{H,t}(i) + (1-n)C_{H,t}^*(i) \\ &= \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\epsilon}\left(\frac{P_{H,t}}{P_t}\right)^{-\eta}\left[(1-\gamma)Y_t + \frac{1-n}{n}\gamma^* Q_t^\eta Y_t^*\right] \end{aligned}$$

Accordingly, market clearing for foreign variety i must satisfy:

$$
\begin{aligned}
Y_t^*(i) &= nC_{F,t}(i) + (1-n)C_{F,t}^*(i) \\
&= \left(\frac{P_{F,t}^*(i)}{P_{F,t}^*}\right)^{-\epsilon} \left(\frac{P_{F,t}^*}{P_t^*}\right)^{-\eta} \left[\frac{n}{1-n}\gamma^* Q_t^{-\eta} Y_t + (1-\gamma^*)Y_t^*\right]
\end{aligned}
$$

Next, we substitute in the expressions $\gamma \equiv (1-n)\lambda$ and $\gamma^* \equiv n\lambda^*$. Further, to portray our small open economy we take $n \to 0$ to get:

$$
Y_t(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\epsilon} \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} [(1-\lambda)Y_t + \lambda^* Q_t^\eta Y_t^*]
$$

$$
Y_t^*(i) = \left(\frac{P_t^*(i)}{P_t^*}\right)^{-\epsilon} Y_t^*
$$

It is clear from these latter equations that while consumption of the Foreign economy affects the Home economy, the opposite does not hold true. At the same time, changes in the real exchange rate do not affect Foreign aggregate demand.

In a symmetric equilibrium, each producer charges the same price and produces the same level of output. For the Foreign economy, this means $P_t^*(i) = P_t^*$ and $Y_t^*(i) = Y_t^*$. Similarly for the Home economy, this means $P_{H,t}(i) = P_{H,t}$ and $Y_t(i) = Y_t$. Furthermore, assuming $\lambda = \lambda^*$ implies:

$$
Y_t = \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} [(1-\lambda)Y_t + \lambda Q_t^\eta Y_t^*]
$$

which is equation (6).